Journal

WATER POLLUTION CONTROL FEDERATION

FORMERLY SEWAGE AND INDUSTRIAL WASTES

Special Features

1959 Literature Review, Part I—Research Committee
Analytical Methods, Sewage

Insurance Needs—Roderick

Mine Drainage—Hert

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Sedimentation with Trickling Filters—Thoman and Jenkins

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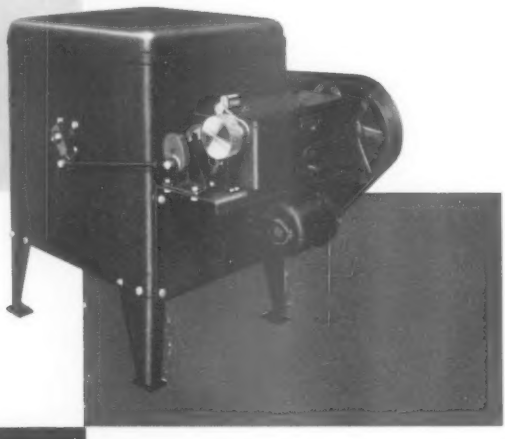

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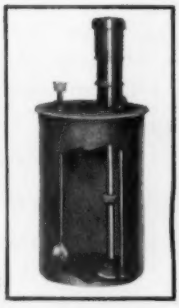

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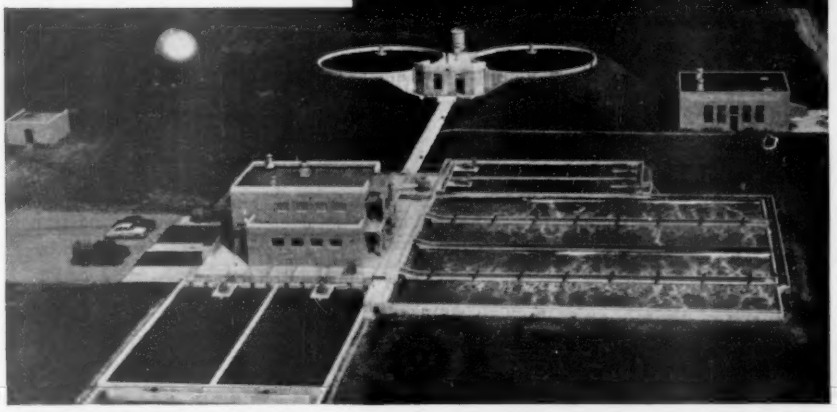

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SUBSCRIPTION RATES: Members of local associations affiliated with the Federation, $8.00 per year. Nonmembers, U. S. and Canada: $10.00; other countries, $11.50. (Foreign subscriptions must be accompanied by International Money Order.) Single copies: United States, $1.25 each; Foreign, $1.50 each.

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Library of Congress Catalog Card Number: 42-19992.

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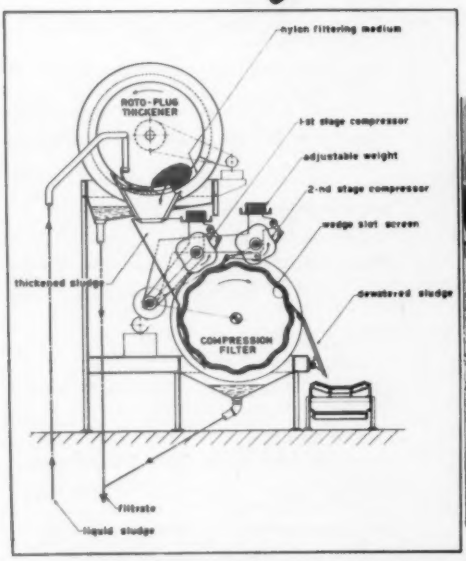

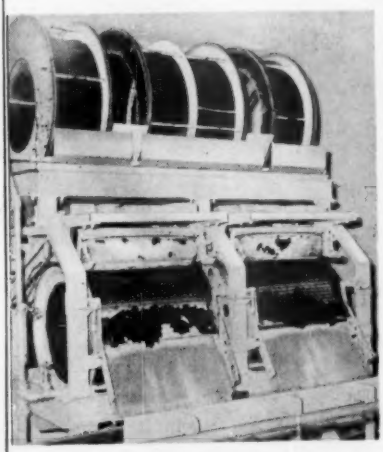

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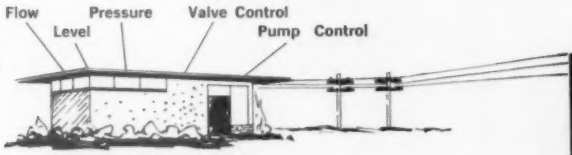

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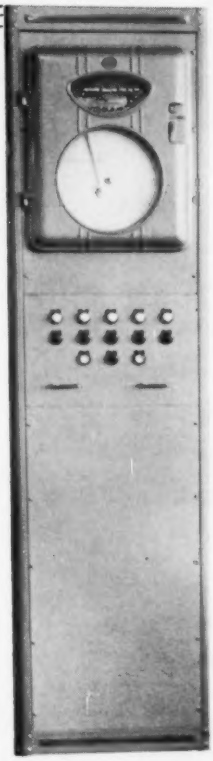

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Central States	June 15–17	Lorraine Hotel, Madison, Wis.
Ohio	June 15–17	Neil House, Columbus
Iowa	June 15–17	Ottumwa Hotel, Ottumwa
ISP (England)	June 21–24	Scarborough, England
Pennsylvania	Aug. 10–12	Pa. State Univ., University Park
South Dakota	Sept. 7–9	Grand Hotel, Watertown
Kentucky-Tennessee	Sept. 12–14	Andrew Jackson Hotel, Knoxville, Tenn.
Missouri	Sept. 25–27	Hotel Governor, Jefferson City
North Dakota	Oct. 5–7	Grand Pacific Hotel, Bismarck
Pacific Northwest	Oct. 20–22	Marcus Whitman Hotel, Walla Walla, Wash.
Rocky Mountain	Oct. 24–26	Broadmoor Hotel, Colorado Springs, Colo.
Canada	Oct. 24–27	Statler Hotel, Buffalo, N. Y.
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Florida	Nov. 13–16	Galt Ocean Mile Hotel, Fort Lauderdale
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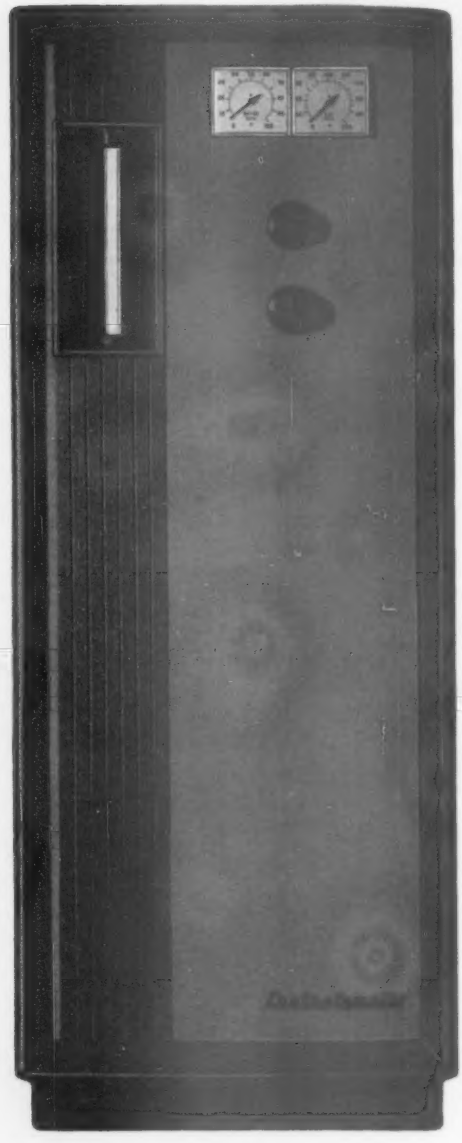

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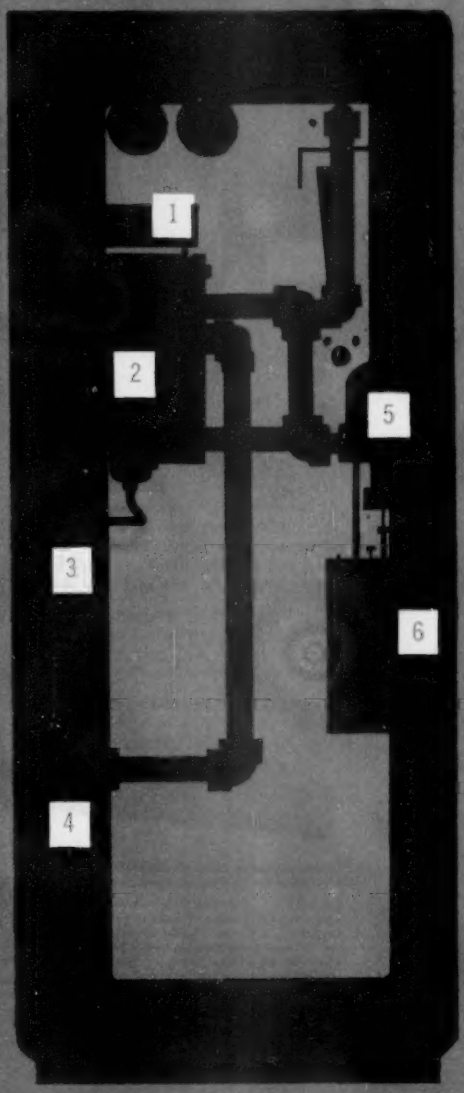
5 Vis-I-Flow Valve
6 Automatic Proportioning Control



FISCHER & PORTER COMPANY INSTRUMENTATION AND CHLORINATION FP

AMERICAN "AIRCOMB" DIFFUSER

WITH SELF-CLEANING NON-CLOG TEETH

Gives All the Aeration You Want . . . *just where and when you want it*

Teeth on *both sides* of the "Aircomb" provide simple, multiple, variable-flow orifices for controlled aeration.

No "*blurps*" at low air flows.

Unique *peaked-dome* design prevents accumulation of solids.

Velocities are self-cleansing.

Variable diffusion capacity as high as 5:1 if necessary.

Nothing to break or need replacement or change.

Fully proved in the field.

NOTHING CLINGS, FLINGS, OR SWINGS

—A TRUE TRIUMPH IN SIMPLICITY, ECONOMY, DURABILITY, AND EFFICIENCY

The AMERICAN "*Aircomb*" has very useful application in pre-aeration, channel diffusion, and activated sludge installations. It is especially preferred where relatively high tank content agitation is required and where other types of diffusers present operating difficulties due to clogging.

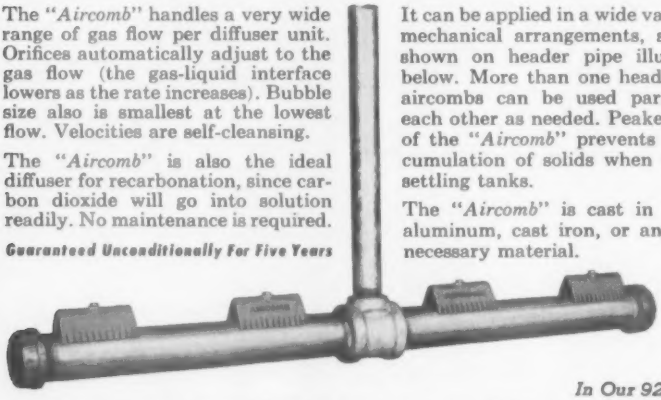
The "*Aircomb*" handles a very wide range of gas flow per diffuser unit. Orifices automatically adjust to the gas flow (the gas-liquid interface lowers as the rate increases). Bubble size also is smallest at the lowest flow. Velocities are self-cleansing.

The "*Aircomb*" is also the ideal diffuser for recarbonation, since carbon dioxide will go into solution readily. No maintenance is required.

Guaranteed Unconditionally For Five Years

It can be applied in a wide variety of mechanical arrangements, such as shown on header pipe illustrated below. More than one header with aircombs can be used parallel to each other as needed. Peaked-dome of the "*Aircomb*" prevents the accumulation of solids when used in settling tanks.

The "*Aircomb*" is cast in bronze, aluminum, cast iron, or any other necessary material.



In Our 92nd Year

Comprehensive Line of Field-Proved *PROCESSES AND EQUIPMENT*

The complete "American" line includes sewage, industrial waste, and water purification equipment; tank and pipeline mixers; deep well turbines; water transfer, clear liquid and waste water pumps. Consult "American" engineers or write for technical data.

AMERICAN WELL WORKS

110 N. BROADWAY — **AURORA, ILLINOIS**

Research, Engineering and Manufacturing — EST. 1868 — Waste and Water Treating, Mixing, and Pumping Equipment

SALES OFFICES: CHICAGO, NEW YORK, AND OTHER PRINCIPAL CITIES

IF YOU DON'T HAVE A TRUCK-LODER *Your Sewer Crew is* *WORKING TOO HARD!*

PATENT 2,892,557

LOADS DIRECT INTO TRUCK

ENDS DUMPING SEWERAGE ON STREETS!

RELIEVES WORKERS OF 3 HARD JOBS!

The **TRUCK-LODER** frees your workers from the hard jobs of manually dumping the bucket on the street — shoveling deposits into the truck, and cleaning up the street.

With the **TRUCK-LODER** two men can accomplish far more than four with conventional bucket machines, thereby freeing the extra men for other important sewer maintenance work.

Users report the elimination of time-consuming operations has increased sewer-cleaning capacity by 40%. They agree that **TRUCK-LODER Bucket Machines exceed all performance estimates.**

Your Flexible representative will be glad to give you facts and figures at your convenience.

Use With Your Present Machines

Use Truck-Loders on the dumping end and your regular machines on the Pull-In end. Net result—two complete, modern Truck-Loder units.

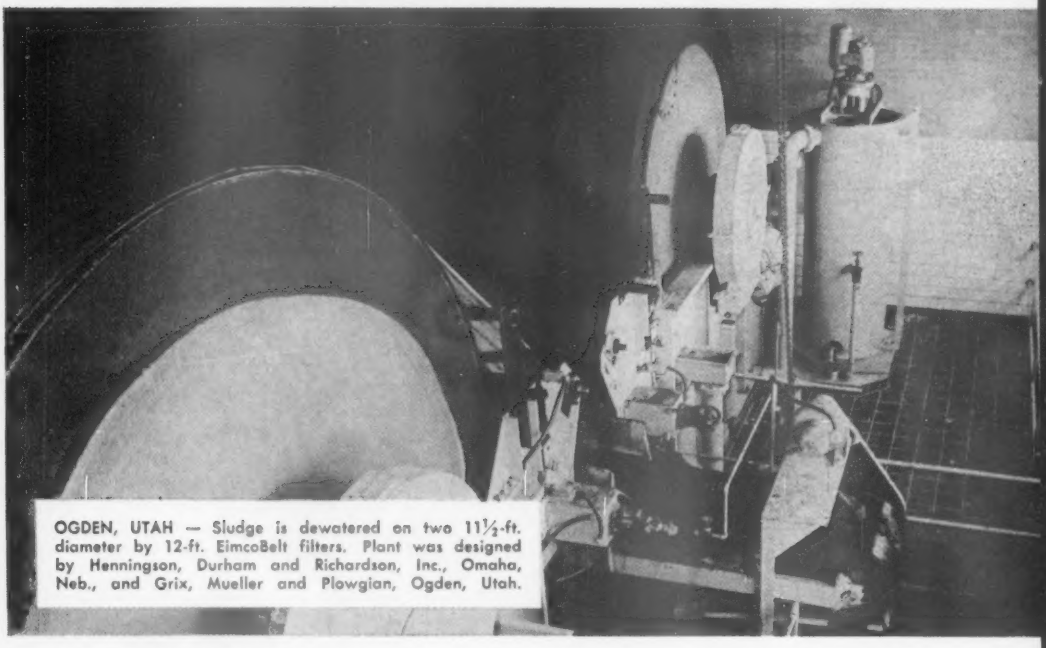
* *

FLEXIBLE INC.

3786 DURANGO AVE., LOS ANGELES 34, CALIF.
1005 SPENCERVILLE ROAD, LIMA, OHIO
415 SOUTH ZANGS BLVD., DALLAS, TEXAS

* *

Job Records Prove EIMCOBELT Rates, Cut Costs, Handling Any



OGDEN, UTAH — Sludge is dewatered on two 11½-ft. diameter by 12-ft. EimcoBelt filters. Plant was designed by Henningson, Durham and Richardson, Inc., Omaha, Neb., and Grix, Mueller and Plowgian, Ogden, Utah.

Rates of 10 and 11 Pounds per Hour, Chemical Costs About $9 a Dry Ton, Filtering Raw Sludge, at Ogden

The ability of the EimcoBelt filter to dewater all types of sewage sludge, economically, has been demonstrated in many disposal plants.

The new $4,800,000 Central Weber Sewer Improvement District plant at Ogden, Utah, for example, employs two EimcoBelt filters for dewatering raw primary and trickling filter sludge.

The sludge at Ogden is probably one of the most difficult to filter in the United States. Influent sewage contains packing house, plating mill and cannery wastes, has often carried unusual amounts of grease, fats, feathers.

Results, with EimcoBelt filters equipped with synthetic fabric media, have been spectacular. After operating techniques were established, cake production has been 10 and 11 lb. dry weight solids per hour. Chemical costs have been $9.11 per ton of dry cake, moisture content about 70%. Maintenance has become a negligible factor in the filter operation.

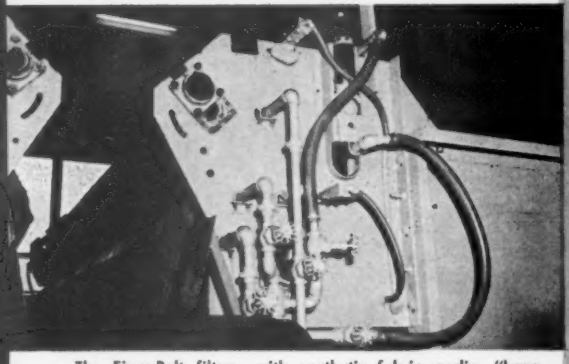
EimcoBelt is the only continuous vacuum filter that successfully removes a fabric type medium from the drum for cake discharge and cloth washing. Blinding is eliminated. Filtrate blow-back is not possible. The EimcoBelt returns a thoroughly cleaned medium to the drum every cycle, and can discharge thin, dry cakes continuously.

For more facts, call the Eimco representative in your area, or write Eimco Filter Division for EimcoBelt Bulletin F-2053.

Filters Increase Sewage Sludge!

Actual 5-Month Operating Record at Ogden, With EimcoBelt Filters

	Raw Sewage (M.G.)	Cake Moisture Per Cent	Dry FeCl₃ Addition Per Cent	Dry CaO Addition Per Cent	Dry Solids Per Sq Ft Per Hr Lb
OCT. 1959	444.01	69.0	1.8	10.1	9.7
NOV. 1959	478.86	70.4	2.3	8.9	10.8
DEC. 1959	376.9	71.2	1.8	8.8	11.6
JAN. 1960	414.54	70.9	1.4	6.6	11.6
FEB. 1960	520.0	69.6	1.6	8.9	10.2



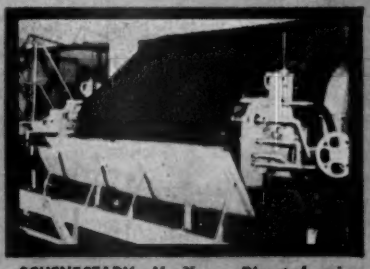
The EimcoBelt filters, with synthetic fabric media, "have been able to handle anything we can feed," according to Marland L. Davidson, plant superintendent, Central Weber Sewer Improvement District.

"ADVANCED ENGINEERING AND QUALITY CRAFTSMANSHIP SINCE 1884"

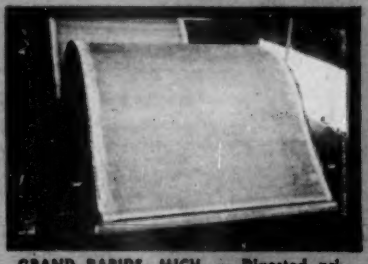
THE EIMCO CORPORATION

EXPORT OFFICE: 51 - 52 SOUTH STREET, NEW YORK, N. Y.
BRANCHES AND DEALERS IN PRINCIPAL CITIES THROUGHOUT THE WORLD

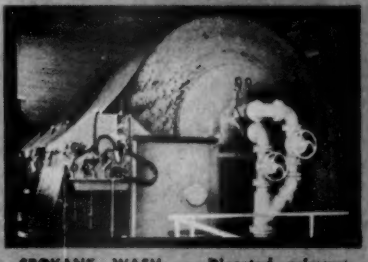
EIMCOBELT Filters are Economical in These Plants, Too, Handling These Sludges



SCHENECTADY, N. Y. — Digested primary sludge is dewatered on 6-ft. diameter by 6-ft. EimcoBelt filter in city's Municipal Sewage Plant.



GRAND RAPIDS, MICH. — Digested primary and waste activated elutriated sludge — two 11½-ft. diameter by 12-ft. EimcoBelts, McNamee, Porter and Seeley, Ann Arbor, Michigan, Engineers.



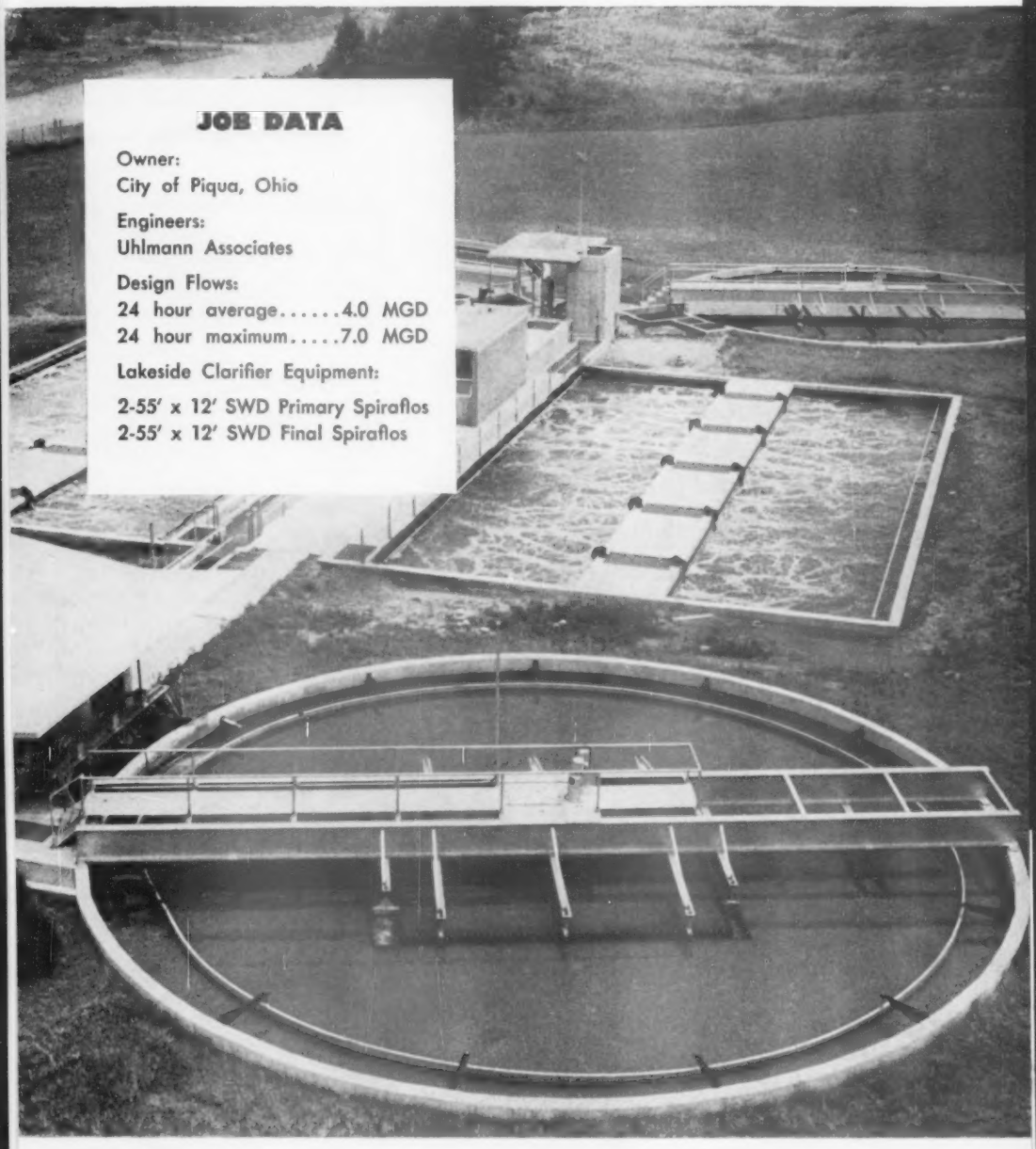
SPOKANE, WASH. — Digested primary elutriated sludge — two 10-ft. diameter by 8-ft. EimcoBelt filters. Crosley and Hansen, Chicago, Illinois, Consulting Engineers.

FILTER DIVISION
634 SOUTH 4TH WEST
SALT LAKE CITY, UTAH — U.S.A.

RESEARCH AND DEVELOPMENT CENTER
301 SO. HICKS ROAD, PALATINE, ILLINOIS

B-586E

Visit the EIMCO Exhibit BOOTHS 64 and 65
AWWA Meeting — Bal Harbour, Fla. — May 15-20



JOB DATA

Owner:
City of Piqua, Ohio

Engineers:
Uhlmann Associates

Design Flows:
24 hour average.....4.0 MGD
24 hour maximum.....7.0 MGD

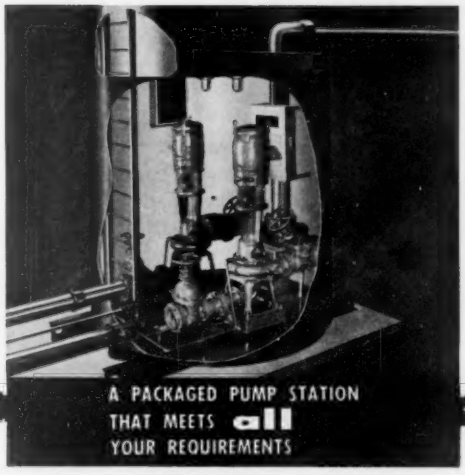
Lakeside Clarifier Equipment:

2-55′ x 12′ SWD Primary Spiraflos
2-55′ x 12′ SWD Final Spiraflos

SPIRAFLOS—give high removals as both primary and final settling tanks—ideal as finals on activated sludge because of the added depth and the flow pattern that traps the light activated particles in the sludge blanket build up. Also a perfect clarifier for the smaller plants particularly where efficient skimming and scum removal are desired.

LAKESIDE
ENGINEERING CORPORATION
222 West Adams St. Chicago 6, Illinois

NOW . . . FROM TEX-VIT

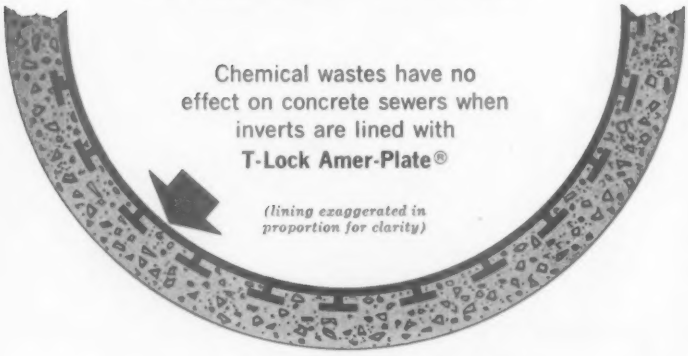


- **ADVANCED DESIGN FOR GREATER EFFICIENCY**
  Compare motor and pump assembly of this duplex sewage pump station with any other and see the TEX-VIT superiority. Individual shaft for each pump and each motor. Four bearings per assembly instead of the customary two. Heavy steel shell, completely protected from corrosion.
- **DIRECT PRESSURE CONTROLS FOR EXTRA RELIABILITY**
  Exclusive TEX-VIT controls are actuated by pressure variations within the wet well. No compressor to maintain; no floats or other moving parts in the wet well.
- **IMPROVED AIR CIRCULATION AND CONDITIONING**
  Extra large blower provides complete change of air every 60 seconds. Air inlet and outlet are at opposite sides of station to prevent short circuiting of air. Refrigeration-type dehumidifier.
- **SUPERIOR COMPONENTS FOR EXTRA DEPENDABILITY**
  Pumps, motors, controls, and other components bear the brand names you would expect to find in a *Who's Who of American Industry*. You know you are getting the best when you specify TEX-VIT.
- **INSTALLATION TESTED AND PROVED**
  TEX-VIT packaged pump stations are setting new standards. Names of muncipal and industrial users furnished on request.
  Let TEX-VIT help you with your sewage lift problems. TEX-VIT also makes pneumatic ejectors and packaged ejector stations.

Write for bulletin No. PS-60

TEX-VIT SUPPLY COMPANY
MANUFACTURING DIVISION
Dept. S-5, Box 117, Mineral Wells, Texas

How to Protect Concrete Sewers from Chemical Wastes


Chemical wastes have no effect on concrete sewers when inverts are lined with
T-Lock Amer-Plate®
(lining exaggerated in proportion for clarity)

T-Lock Amer-Plate is a high polymer PVC sheet, easily cast into pipes, tunnels and structures to form a partial or complete 360° protective lining. Used in inverts, it permanently protects concrete from corrosive chemical effluents. In arch areas, it positively stops oxidized H_2S corrosion. T-Lock is also highly abrasion resistant; impartial tests show that it abrades at only 1/70th the rate of concrete.

The fact that T-Lock ends erosion and corrosion problems in industrial and municipal sewer systems is attested to by more than five million square feet now in use. Write for complete data on this maintenance-saving lining before designing your next sewer.

Applicators strategically located throughout U. S. and Canada

Amercoat® CORPORATION

Dept. SE • 4809 Firestone Boulevard • South Gate, California

921 Pitner Ave. Evanston, Ill. | 360 Carnegie Ave. Kenilworth, N.J. | 2404 Dennis St. Jacksonville, Fla. | 6530 Supply Row Houston, Texas

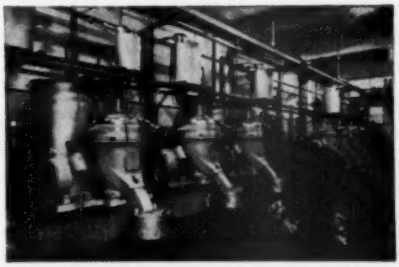
11e

FLUIDICS

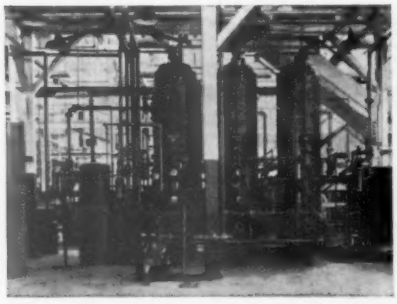
is a Pfaudler Permutit program providing

the know-how
the equipment
and the experience
for solving problems
involving fluids

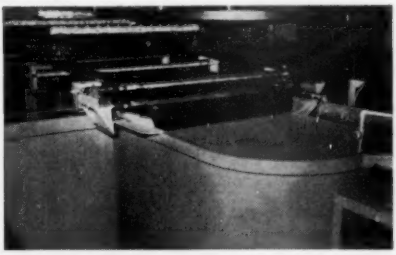
FOR WASTE TREATMENT, the Fluidics program provides a wide range of specialized equipment and technical service to help you efficiently recover valuable materials and easily dispose of unwanted wastes.



Dewatering Sludges. Titan Centrifuge exerts settling power up to 7800 times gravity. Concentrates slimes and clarifies liquids. Precisely separates two liquids and a solid in a single pass. Dewaters plating wastes, protein fines and flocculent precipitates. Recovers oil from tank bottoms, fat from waste, and pulp from white water. Saves product, filter aid, power and maintenance.



Purification of liquids and recovery of dissolved minerals from plating solutions, pickling baths, textile wastes, process solutions and similar fluids are assured with unique effectiveness by Permutit Ion Exchangers. Recovery of valuable materials often pays for equipment within a short time.

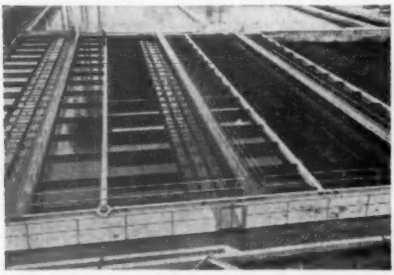


Flotation clarification of fluids containing fats, oils, greases, organics and colloidal suspensions is done quickly, effectively and economically with the Permutit Colloidair Separator.

Add to this equipment our Simplex meters and flow controllers, Permutit chemical feeders, filters and vacuum degasifiers, Ranarex CO_2 indicators and recorders, and Pfaudler evaporator systems, and you get an idea of the scope of this program in just the waste treatment area of fluid processing. Yet Fluidics is a program that provides more than just equipment. You can get complete engineering assistance as well as expert advice based upon more than 50 years' experience in fluid waste control.

For more information on how Fluidics can help in your waste treatment program, contact our Permutit Division, 50 West 44th Street, New York 36, N. Y.

In Canada: 207 Queen's Quay W., Toronto 1, Ontario.

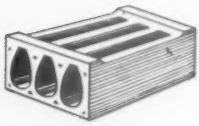


Sludge blanket clarification of fluids requiring removal of suspended solids such as fly ash, precipitates, turbidity, etc. is accomplished with high efficiency by the Permutit Precipitator.

PFAUDLER PERMUTIT INC.

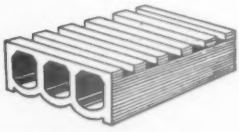
Specialists in FLUIDICS . . . the science of fluid processes

DEMAND WILL RISE NOW for SEWAGE and WASTES TREATMENT



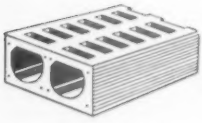
NATCO

Natco Corporation
Pittsburgh 22, Pa.



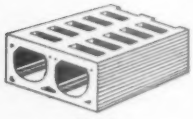
TRANSLOT

Cannelton Sewer Pipe Co.
Cannelton, Ind.



ARMCEE

Ayer-McCarel Clay Co., Inc.
Brazil, Ind.



BOSCO

Bowerston Shale Co.
Bowerston, Ohio

Sparked by articles in Readers' Digest, Good Housekeeping and U. S. News, some fifty million readers already have been exposed this year to fresh fears of pollution of public water supplies.

Right or wrong, we can look now for great upsurge of demand for adequate treatment of all wastes entering our streams and other waters.

The best answer is to build trickling filters for treatment. And the best trickling filters are those with TFFI specification vitrified clay underdrains. For it is inherent in clay to resist successfully the ravages of acids, alkalis and bacteriological action.

TFFI floor blocks are made in modern plants under rigid controls of quality that no substitute material can even approximate. (Only with them can you get a 50-Year Guarantee.)

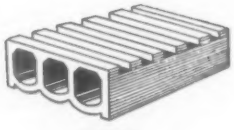
ENGINEERS:

If you have not received yours, write nearest member of this Institute for the new TFFI Trickling Filter Handbook containing also the new approved ASTM Specifications C 159-59T for your use in designing trickling filters.

TRICKLING FILTER FLOOR INSTITUTE

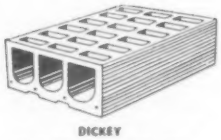
POMONA

Pomona Terra-Cotta Co.
Pomona, No. Car.



TRANSLOT

Texas Vitrified Pipe Co.
Mineral Wells, Texas



DICKEY

W. S. Dickey Clay Mfg. Co.
Kansas City 6, Mo.

It's HERE!

25-Year Protection on Pneumatic Ejectors

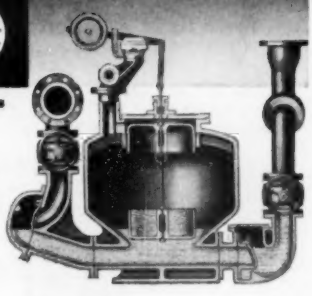
Only Yeomans dares to back specifications with this long-term warranty...

SHONE®
PNEUMATIC EJECTOR
Mechanically-Controlled
Twenty-Five Year Warranty
Subject to the limitations herein contained, YEOMANS BROTHERS COMPANY warrants its mechanically-controlled Shone Pneumatic Ejector against defects in workmanship and materials under normal use and service for twenty-five (25) years after installation as provided in factory recommendations. The Company's responsibility under this twenty-five year warranty is limited to replacing or repairing without charge, f.o.b. its works, any of the following components: sewage or waste receiver, mechanical air and exhaust control and the Shone inlet and discharge check valve. All other parts are subject to the manufacturer's warranty of one year.
Written notice must be given to the Company immediately upon discovery of any defect. The Company shall have the option of requiring the return of a defective component or material, transportation prepaid, before accepting it a claim. In no event shall YEOMANS BROTHERS COMPANY be responsible or held liable for delay or damages of any kind or character resulting from or caused directly or indirectly by any defective component or material. This warranty shall not apply to any component or material repaired or altered outside of the Company's works unless the Company's written approval in that respect is first obtained and its allowance will be made for such repairs or alterations without the written consent or approval of the Company.
This Warranty is in lieu of all other warranties, expressed or implied, and is in lieu of all other obligations or liabilities on the part of the Company. No other person is authorized to vary the terms or provisions hereof in any respect.
YEOMANS BROTHERS COMPANY
D. W. Burgoon
PRESIDENT

YEOMANS

1999-7 North Ruby Street, Melrose Park, Illinois

This is the SHONE® with mechanical controls. It is the original pneumatic ejector. The first SHONE® was installed in 1870.



E-5904

WORLD'S LARGEST AND BEST LINE OF PNEUMATIC EJECTORS

A-M Flat-Base Pipe used in $120,000,000 expansion of Chicago's O'Hare Field

Utility tunnel designed to withstand 100,000 lb. jet wheel loading

A jet landing strip must necessarily be level—virtually free of dips and cracks. That's why A-M Flat Base Pipe was used for a watermain gallery beneath O'Hare Field's runways as part of its multi-million dollar modernization program—because A-M Concrete Flat Base Pipe has the necessary *rigidity* to resist sagging and tight joints to prevent infiltration. The result is a *dry* utility tunnel —a *strong* tunnel designed to withstand 100,000 lb. jet wheel loadings with complete safety.

Quickly installed, precast Flat Base Pipe can save as much as *30%* in the construction of utility galleries, underpasses, cattle passes and utility manholes. For full details write to:

Contractor for installation of this A-M Flat Base watermain gallery: S. J. Groves, Chicago; Architects-Engineers: Naess & Murphy, Chicago.

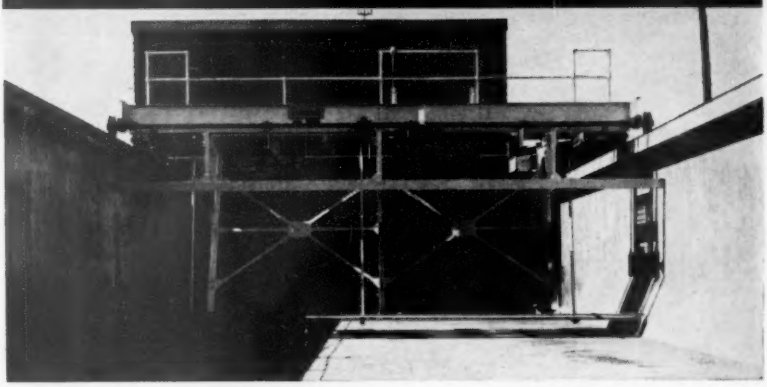
A·M

AMERICAN-MARIETTA COMPANY

CONCRETE PRODUCTS DIVISION

GENERAL OFFICES:
AMERICAN-MARIETTA BUILDING
101 EAST ONTARIO STREET, CHICAGO 11, ILLINOIS, PHONE: WHITEHALL 4-5600

HARDINGE CLARIFIERS for rectangular tanks



The Hardinge Rectangular-Type Clarifier is similar in operation to an industrial, overhead crane. It travels on two rails, on the outside walls of the settling tank, scraping settled solids to a sludge hopper at one end. A skimmer may be added to remove scum and floating material from the tank surface on the "return trip" of the Clarifier.

Advantages of the Hardinge unit are these:

(1) Settling tank installations may be made in limited space (as opposed to the circular type clarifier).
(2) Maximum use of common wall construction is possible, when there are two or more tanks involved.
(3) A single Clarifier mechanism can operate over two adjacent settling tanks (duplex arrangement) reducing equipment cost.
(4) Clarifier equipment cost does *not* increase with tank length.
(5) All essential working parts are above liquid level.

Hardinge has installed more than 80 Rectangular Clarifier units for municipal sewage treatment, industrial water treatment, and for liquid wastes at paper plants, textile mills, and oil refineries—processing in excess of 350 million gallons of liquid daily.

Write for Bulletin 35-D-16

HARDINGE
COMPANY, INCORPORATED

YORK, PENNSYLVANIA • 240 Arch St. • Main Office and Works

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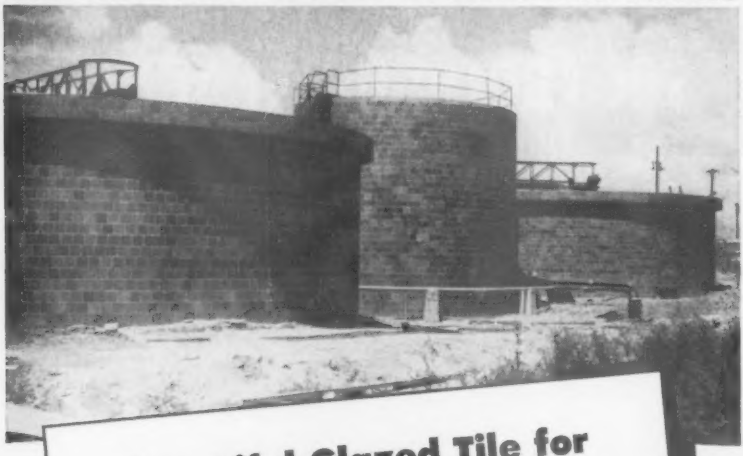
Effluent and Water Treatment Tanks



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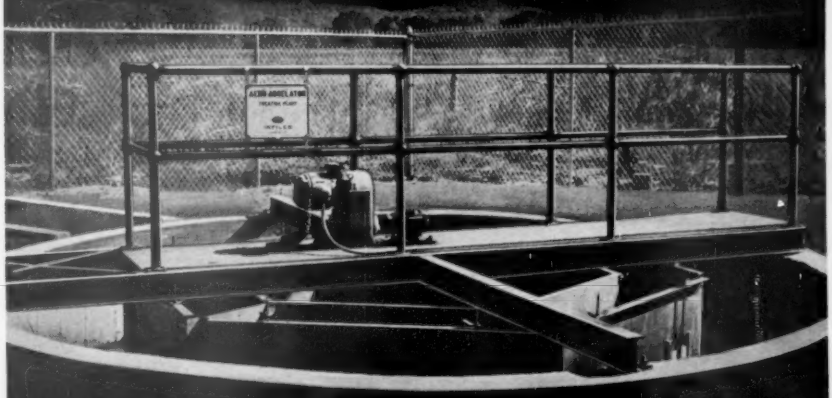

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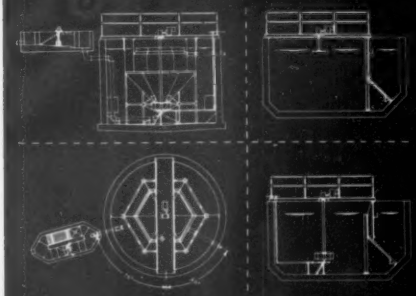

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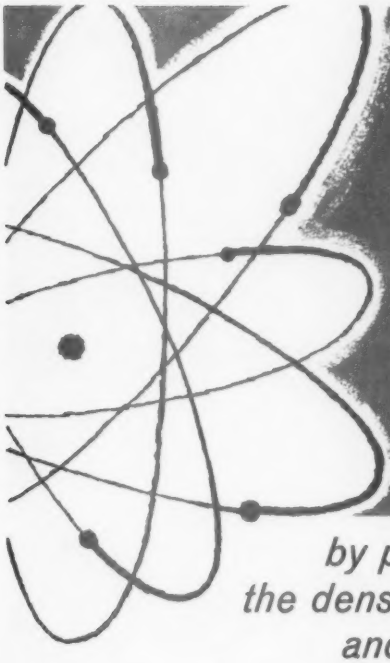

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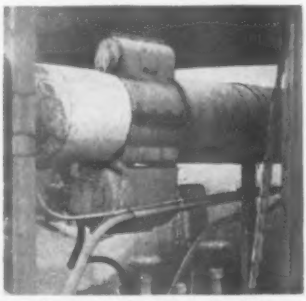

Caustic evaporator employing Ohmart Density System to maintain a constant percent of solids.

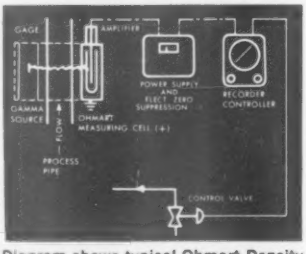

Diagram shows typical Ohmart Density Control System where control of liquid density is by actuation of a valve.

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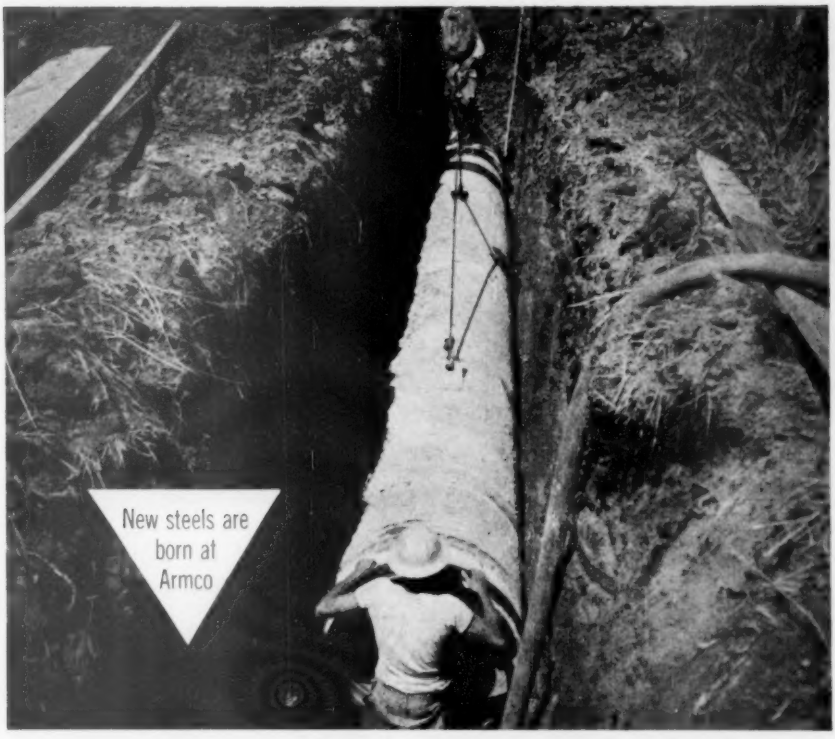
Merced, California, installs eight miles of Armco Pipe



Large population increases in the area around Merced, California, made it necessary for that city to institute a sewage expansion program. More than 8 miles of Armco ASBESTOS-BONDED SMOOTH-FLO® Sewer Pipe was used on the job.

Photo shows a section of SMOOTH-FLO being installed in Merced. Note the relatively narrow trench, reducing excavation and backfill. Water covered the trench bottom while pipe sections were joined.

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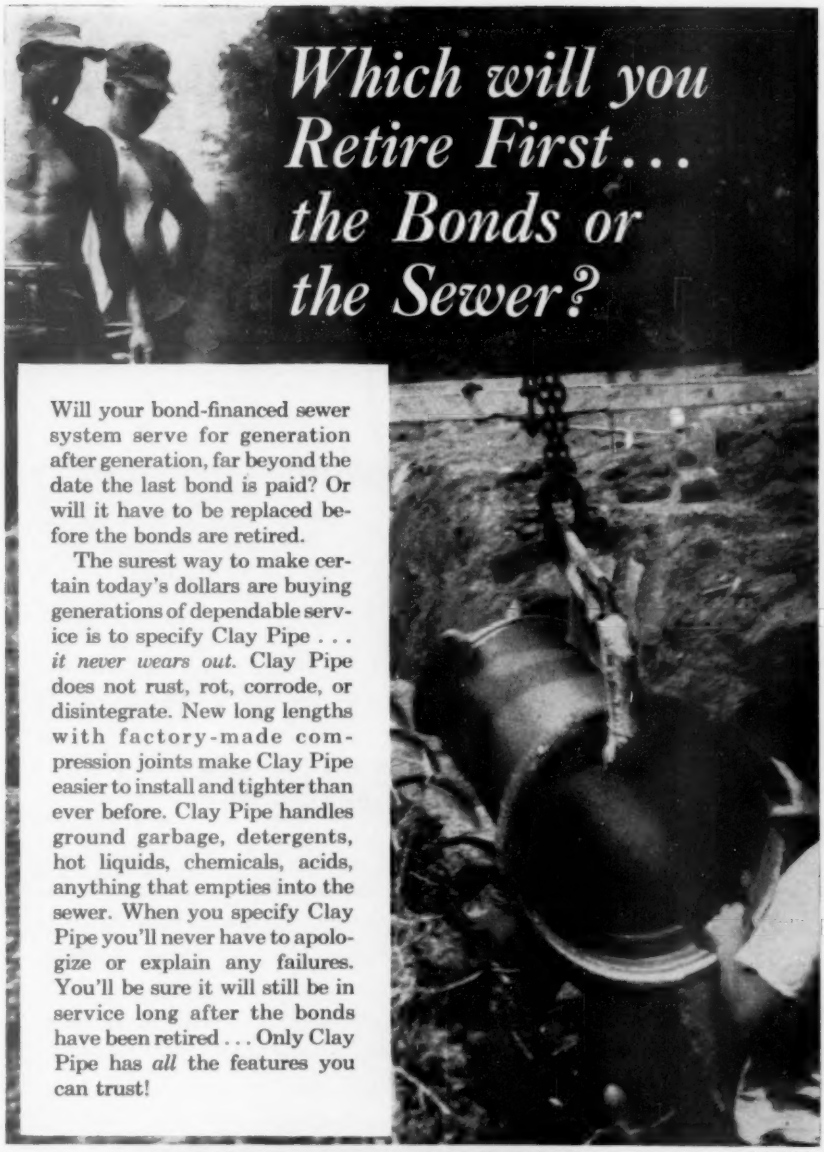

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Will your bond-financed sewer system serve for generation after generation, far beyond the date the last bond is paid? Or will it have to be replaced before the bonds are retired.

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Clean, sparkling river water flowing into Wyoming's Glendo Reservoir makes it a great place for water sports!

The Glendo Reservoir on the North Platte River was ideal for recreation except for the untreated sewage being poured into the river by every town for 100 miles upstream. Then they all joined in a highly successful clean-up campaign. Ridding the river of dangerous wastes not only took care of a serious public health problem—it gave everyone a delightful new recreation attraction after the dam was built. Boating, swimming and fishing bring many vacationers to the area each year.

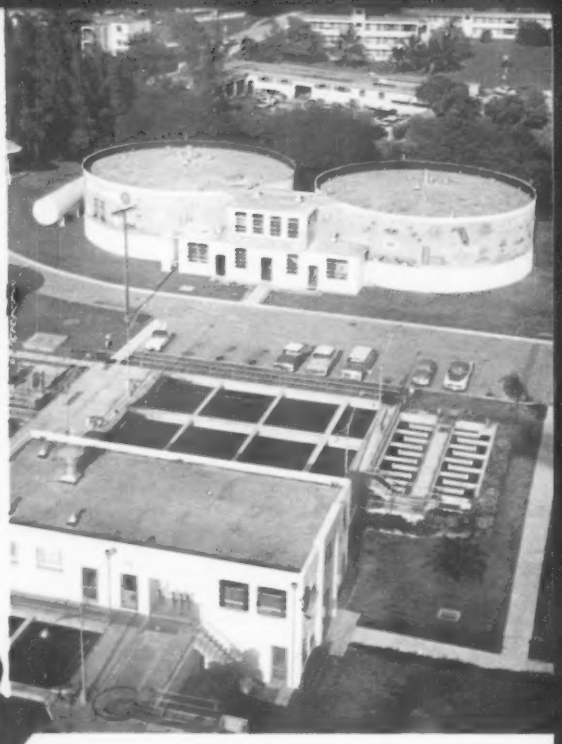
"They're catching bass in the Walnut River for the first time in 35 years!" say local fishermen. Oil field, refinery and municipal wastes spoiled one of the prettiest rivers in southern Kansas. But the communities and industries along the Walnut River set up a *pollution abatement program* and each cooperated to carry it out. They've built new sewage treatment plants, eliminated oil field brines and set up waste treatment facilities at refineries. The river is being returned to its original beauty—a natural resource to be proud of!

"Our water clean-up brought us new industry and jobs," says Mayor J. E. Keech, Cumberland, Maryland. The city built a new sewage treatment plant (above) that will take care of all home and factory wastes, even with the growth expected in the next ten years. And that's one important reason Pittsburgh Plate Glass Company came to Cumberland! Their new factory will bring jobs for nearly a thousand people.

Right next door to luxury homesites . . . treatment plant doubles as popular marina!

An attractive and useful asset to the community is the sewage treatment plant at Clearwater, Florida. Its appearance would do credit to a fine yacht club. There are 45 boat slips for public use at the Marina Station. Planned for the future, the plant's capacity for treating wastes will be more than adequate for the population expected when the area is fully developed.

Treatment plant on a boulevard wins favor for engineers and city officials



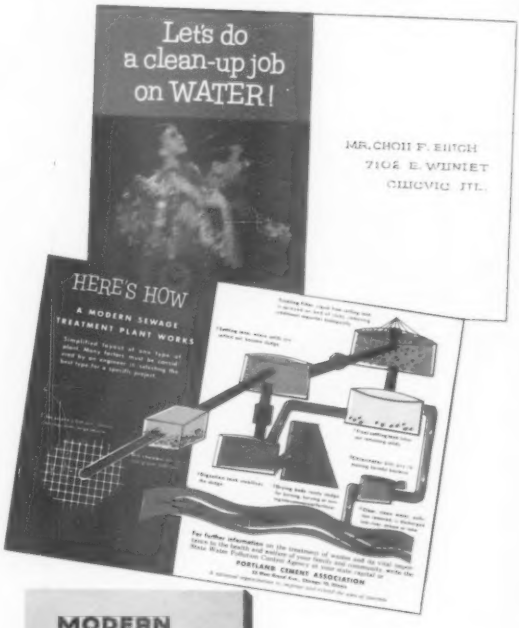
The Coral Gables, Florida, sewage treatment plant is truly a civic showplace. Walls are decorated with colorful scenes by famous artist John St. John. A well-designed, odor-free treatment plant is a credit to a community wherever it's located!

HERE'S HELP IN GETTING PUBLIC SUPPORT FOR ACTION ON POLLUTION PROBLEMS IN YOUR AREA

The pages you have just read relate a story that needs telling to the public. That's why PCA is reprinting this colorful insert—with a new fourth page—folded for easy mailing (shown at right.)

This mailing piece is available in quantity for use locally where help is needed to inform the public as to the urgency for obtaining adequate pollution control facilities.

For further information about this folder, or for help of any kind in planning your clean-up programs—just call on PCA.



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1959 Literature Review

A REVIEW OF THE LITERATURE OF 1959 ON WASTEWATER AND WATER POLLUTION CONTROL

By H. Heukelekian, *Chairman*, R. M. Manganelli, *Vice-Chairman*, E. J. Berg, H. F. Clark, C. H. Connell, W. E. Dobbins, G. P. Edwards, M. B. Ettinger, D. G. Foulke, T. deS. Furman, I. Gellman, H. Harding, C. Henderson, R. D. Hoak, P. E. Gaffney, W. M. Ingram, P. W. Kabler, M. Katz, F. W. Kittrell, N. J. Lardieri, H. G. Luley, P. H. McGauhey, W. A. Moore, N. L. Nemerow, R. Porges, E. R. Roth, A. J. Steffen, C. Straub, C. M. Tarzwell, W. W. Towne, H. A. Trebler, E. C. Tsivoglou, E. Weisberg, and R. L. Woodward

Research Committee, Water Pollution Control Federation

This section of the Literature Review covers analytical methods and sewage. It will be followed by two other sections dealing with industrial wastes (including radioactivity) and stream pollution. These will be published in the June and July issues of This Journal.

ANALYTICAL METHODS

Biochemical Oxygen Demand

The problem of providing the proper seed in the BOD determination has been studied by numerous investigators. Lee and Ostwald (17) in their attempt to produce a viable easily prepared seed which would remain constant over a period of time tried both a frozen and lylophilized seed. They found, however, that the ultimate BOD obtained with either type of seed was lower than that using the "Standard Methods" technique. Freezing proved to be superior to lylophilization in that the BOD values obtained approached those using fresh seed. However, on the other hand, lylophilization was superior to freezing in that more reproducible results could be obtained with a "standard substrate." The authors concluded that either type of seed may be used over a limited period of time where reproducible results are desired. The same authors (18) investigated the effect of the composition and magnitude of the bacterial population on the rate of oxidation using the Warburg method. They conclude from their study:

1. That for a given total number of bacteria present originally, the ultimate BOD increases to a maximum in direct proportion to the number of different species present.

2. The reaction rate attained by a given seed is a function of the number and variety of organisms originally present.

3. That the maximum uptake of oxygen occurred during the first 18 hr when the apparent population was small. Following this period the up-

take decreased with increasing population growth.

4. That a seed dilution of 100 to 1 appears to be maximum for accurate Warburg determinations.

Orford and Matusky (23) compared the BOD results obtained by the standard 5-day test at 20° to those obtained at shorter intervals (1, 2, and 3 days at 20°) and (1 and 2 days at 37°). The authors found that the variation in the 1- and 2-day tests at 37° were greater than for the same periods at 20°. The 2-day test at 20° showed about 25 per cent more variation than the 5-day test at the same temperature. With raw and settled domestic sewage the 5-day BOD could be estimated from the 2-day results. The variation, however, was about twice that obtained with the 5-day period. This variation increased to three times when the 1-day results were used to estimate what the 5-day demand would be.

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Chemical Oxygen Demand

No significant contributions to present knowledge concerning the chemical oxygen demand determination have appeared in the past year. There were only a few papers discussing the subject.

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Wilson, A. L., "Determination of Organic Matter in Water by Oxidation with Potassium Permanganate." *Jour. Appl. Chem.* (Brit.), **9**, 510 (1959).

Dissolved Oxygen

The instrumental determination of dissolved oxygen in various substrates has been studied by a number of investigators during the past few years. It should be pointed out, however, that in the case of most of these instrumental methods further work is necessary to place them on a practical basis.

Tyler and Karchmer (32) and Karchmer (13)(14) designed a portable instrument utilizing the dropping mercury electrode. With most such instruments, the conventional drop time is too slow and results in an unsteady current, especially when used in a boat. These authors employed a drop time of about 0.25 sec which produced a current relatively insensitive to agitation or to sample flow. This low drop time was obtained by mounting the electrode in a horizontal rather than vertical position in the electrolytic cell. It is claimed that the method is applicable in sample pH range between 4.5 and 11.0 and at salt concentrations between 0.001 and 0.05M. If the salt concentration is outside these limits, gelatin is added. This method can be used on either stationary or flowing samples.

When the oxygen utilization of activated sludge is followed polarographically a two-stage characteristic line is obtained which is supposedly due to settling of the sludge particles. Potos (26) used a magnetic stirrer in an attempt to overcome this difficulty. When the stirrer was operated at the lowest speed necessary to keep the sludge particles in suspension errors due to turbulence, collision of the particles with the forming mercury drop and the magnetic field of the stirrer were minimized.

Macklin *et al.* (19) carried out further work with a continuous recording DO analyzer. The main objectives for this instrument were to record the per cent saturation between 0 and 150 per cent in waters containing up to 2,000 mg/l of suspended solids, a 90-per cent response to DO change within 20 min; to weigh less than 100 lb; and to require no mechanical adjustment at intervals less than 48 hr. This instrument was tested on river water, sewage, and a sewage lagoon, and was found to be well within the objectives sought. Due to frequency sensitivity the instrument cannot be used with mobile power units.

Griffiths and Jackman (10) developed an automatic titrator using ferrous ammonium sulfate as the titrant in the determination of dissolved oxygen. The electrode pair consisted of a glass reference electrode and a platinum indicator electrode. The sample was prepared by the addition of 1 ml $MnSO_4$ (48 per cent) and 1 ml KOH (70 per cent) to 120-ml samples. The mixture was acidified with H_2SO_4 and H_3PO_4 and titrated in the automatic titrator. The average deviation from the mean using the ferrous method was 1.85 per cent and 3.4 per cent using the Winkler method.

Beadle (2) modified the Winkler iodine-difference method in the determination of dissolved oxygen in swamp waters by the addition of iodine along with the clarifying agents to a single sample from which two smaller samples were siphoned. The titration end point was improved by using a magnetic stirrer. The spectrophotometric determination of the iodine was found to be much more rapid and as accurate as the titration method. An accuracy of $\pm$ 0.2 mg/l oxygen is claimed.

Additional References

Knapp, W. G., "Internal Electrolysis-Coulometric Method for Determination of Small Quantities of Oxygen." *Anal. Chem.*, **31**, 1463 (1959).

Alcock, G. P., and Coates, K. B., "Indigo Carmine Method for the Colorimetric Determination of Low Concentrations of Dissolved Oxygen in Water." *Chem. and Ind.*, **19**, 554 (1958).

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Wright, J. M., and McGrath, P. E., "Preliminary Report on a New Method of Analyzing for Oxygen Dissolved in Water." Office of Tech. Services, Dept. Commerce, Washington, D. C. 13 pp. (1957).

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Todt, F., "Experiences with Electrochemical Oxygen Determination in Liquids in Recent Years." *Chemiker-Ztg.* (Germany), **83**, 483 (1959); *Chem. Abs.*, **53**, 22632 (1959).

Nitrogen Compounds

Research workers in the field of sanitary chemistry continue to seek better methods for the determination of NO_3^--N than those currently being used as standard procedures. Prochazkova (27) used N_2H_4 in the presence of a copper catalyst to reduce NO_3^- to NO_2^- at a pH of 12.3, the resulting nitrite being determined by the Griess reaction. The excess N_2H_4 is removed by acetone. It is claimed the reduction is 92 per cent complete and the error is 2 per cent for nitrate concentrations between 0.01 and 0.4 mg/l. Me-Keng *et al.* (22) used Nelson's method for the determination of nitrates. However, these workers added a trace of $CuSO_4$ to the acetic acid reagent to increase the sensitivity and removed any nitrites by the addition of sodium azide. Their method is claimed to determine nitrate concentration as low as 0.02 mg/l and to be more accurate and rapid than the phenol-disulfonic acid procedure. Shafershtein *et al.* (29), as other workers have done, carried out the reduction of

NO_3^- to NO_2^- by using zinc dust in a medium 0.75 N in NH_4OH. A reduction of 94.5 per cent is claimed for nitrate concentrations between 0.01 and 10 mg/l. Above 10 mg/l the reduction is carried out using increased proportions of the reagents. It is claimed that Cl^-, $SO_4^=$, and urea do not interfere, but that Fe(III) and Mn must first be precipitated with Na_2CO_3. Hoather and Rockham (11) used the nitrate absorption band at 2,100 Å for its determination. The authors claim that the absorption by organic matter at this wave length is negligible and by measuring the absorption of organics at 2,750 Å (where nitrate absorption is extremely low) an empirical correction can be made. In some cases the nitrate calculated from the ultraviolet determination was higher than that obtained by chemical methods. The authors attempted to account for the oxidation of NH_3 in raw sewage to nitrate with the nitrate found in the effluent but were unable to do so. (*Note*—Chemical methods also fail in this respect.) The anomalous results were attributed to the microbiological formation of an intermediate compound, $Na_2N_2O_x$, in which x is between 2 and 6. On standing these intermediates break down to form NO_3^-.

Fuls and Veatch (6) used the ninhydrin reaction for the determination of protein nitrogen. The authors claim a quantitative accuracy for concentrations of the NH_3-N formed as low as 1. They used a 0.5 M citrate buffer not only for enhancing the developed color but also to tie up metal ions which interfere. This buffer also prevents interference from neutral salts.

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Sulfur Compounds

Claudy *et al.* (4) determined sulfates automatically by the addition of the sample at the rate of 30 drops each minute to a continuously flowing barium chloride-gelatin reagent, the gelatin acting as a protective colloid. The concentration of $BaSO_4$ sol for full-scale instrument reading is less than 100 mg/l. Greater sensitivity can be obtained by increasing the depth of the cell or by reversing the flow ratio of sample to reagent. Voslov and Sampson (34) also used the nephelometric method for the determination of sulfate. These authors, however, measured the scattered light by means of several photocells surrounding the sample tube instead of the transmitted light. In their investigation they studied the effects of precipitation volume, time interval between precipitation and measurement, the effect of $BaCl_2$ crystal size, rate of dissolution and effect of temperature on precipitation of the $BaSO_4$ sol. For stabilization of the sol a solution of 20-per cent glycerin in ethanol was added. The standard curve used was not linear but was reproducible.

Goldman (8) improved the amperometric determination of sulfides by utilizing a back titration method. As originally used the method was applied to waters relatively free of gross pollution. However, by increasing the concentration of the reagents the method can be extended to polluted waters. The method is based on the titration of a 10-ml volume of 0.025 N I_2 solution added to a 200-ml water sample with phenyl-arsenoxide. A second 10-ml volume of the same I_2 solution is added and the titration repeated. The method is reputed to be

more accurate and simpler than the methylene blue procedure.

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Cyanogen Compounds

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Halogen Compounds

Jones and Kehoe (12) used a silver-silver chloride electrode for determining chloride concentrations between 1 and 10,000 mg/l on a continuous basis. The electrode used was the conventional laboratory electrode adapted by Beckman for continuous measurement. The electrode used was sensitive to oxidizing agents and also slightly to sunlight. However, it is claimed that the analyzer is suitable for stream surveys and industrial waste monitoring. Malmstadt and Winefordner (20)(21) employed a null-point potentiometric method for determining chlorides in the concentration range of 0.03–30 mg/l. This null-point was first set with a reference solution of known chloride concentration. If the unknown chloride concentration was greater than that in the reference solution it was diluted with $\underline{M}$ H_2SO_4 until the null-point was again reached. However, if it was less concentrated a chloride solution twice the strength of the reference solution was added to the unknown. The second reference gives a detailed description of the apparatus used and the technique to be followed. The precision and recovery of the method are claimed to be 0.01 mg/l of Cl^-.

Post and Moore (25) determined chlorine dioxide in concentrations between 0.05 and 1.5 mg/l by reacting it with 1-amino-8-naphthol-3, 6 disulfonic acid at a pH of 4.1–4.3. The intensity of the bluish-pink color produced was measured at 525 mμ. Interference from chlorine was eliminated by the addition of malonic acid. Of the diverse ions tested for interference, polyphosphate was the only one found to produce any interference. Shchegol (30) used both a spectrophotometric and polarographic method for determining ClO_2 in the presence of chlorite. The absorption of the mixture was first determined at 400 mμ (for ClO_2) and then at 260 mμ to determine both chlorite and chlorine dioxide. The relative error of the method is claimed to be ± 8 per cent. ClO_2 was also determined polarographically in a K_2SO_4 solution (buffered with NaH_2PO_4) at pH 7.0. The voltage range used was 0.0 to 0.5. By modification, chlorite could also be determined by this method. Katz and Heukelekian (15) carried out further studies in the determination of chlorine by the cyanogen-chloride method. The authors state the method is applicable to free halogen as well as compounds containing available halogen. The method was found to be applicable to chlorine

concentration between 0.05 and 1.09 mg/l. Variations in temperature between 5 and 30°C did not affect the reaction. Any interfering ions present could be compensated for by using a baseline technique.

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Organic Compounds

Ullmann and Sanderson (33) compared n-hexane with petroleum ether in the determination of grease in sewage by the Soxhlet extraction method. The term "grease" is divided into two fractions, namely hydrocarbons of petroleum origin and fatty matter of animal or vegetable origin. To sewage were added increments of motor oil (SAE-20) and Crisco. The hydrocarbon portion of the grease recovered was separated by the alumina adsorption technique and between the limits studied (44 to 203 mg of oil) the recovery was about 91.5 per cent. The remainder of the grease was considered fatty matter with a recovery of 103 per cent. This higher percentage recovery was due to the adsorption of polar matter by alumina. The authors propose the substitution of n-hexane for petroleum ether since the former solvent has a definite boiling point; there is no change in the solvent during distillation; and the accuracy and precision are not affected.

Webster and Holliday (35) modified the methylene blue method of Longwell and Meniece and claim results comparable to the long infra-red method. The essential feature of the method was hydrolysis to eliminate sulfides and those hydrolyzable substances causing interference. The surfactant was then extracted with n-heptylamine which was subsequently destroyed by boiling, the isolated surfactant being then determined by the methylene blue procedure. Ginn and Church (7) used a mixed bed ion exchange column for the separation and determination of both anionic and nonionic surfactants. The authors claim the method is applicable to the common surfactants encountered but not to those affected by acids or alkalies. The mixed bed method is more rapid for nonionics than those procedures employing separate resins.

The separation and determination of nitriles in wastewater samples have been studied from various angles. Babrova and Kudasheva-Matveeva (3) determined the half-wave potentials and I_d values for various nitriles in 0.14 N LiCl in 50-per cent ethanol. The authors claim direct linearity between nitrile concentration and diffusion current which enables the method to be used for the estimation of nitriles. Stepanek *et al.* (31) in their determination of acrylonitrile used a sample size containing between 0.5 and 100 mg of the compound. To this they added isopropyl alcohol and H_2SO_4 and then saturated the mixture with NaCl. The azeotropic mixture was then distilled into a mixture of thiourea and HCl and chromatographed.

The determination of organic acids in wastewaters still is subject to improvement and still is being studied by various workers. Dyatlovitskaya (5) determined volatile aliphatic acids by keeping the volume of the distillation mixture constant to prevent inter-

ference from chlorides and thiocyanates. The distillate was refluxed to expel CO_2, H_2S, and SO_2 and then titrated in the usual manner. The author used this procedure on wastewaters from the by-product coke industry. Bars and Fikhman (1) separated naphthenic from humic acid in waters by treatment with acidified benzene or $CHCl_3$. Humic acid was recovered as a brown layer on top of the solution, whereas naphthenic acid is dissolved in the benzene or $CHCl_3$. This latter acid is finally determined turbidimetrically and the humic acid colorimetrically.

With the continued steady increase in the amount and variety of insecticides being used it has been necessary to devise analytical methods to detect concentrations below the toxic level to aquatic life. Rosen and Middleton (28) by a combination of carbon adsorption, chromatography, and infrared analysis were able to identify less than 10 ppb of about eight chlorinated insecticides in river water. By this same procedure a quantitative estimate of the concentrations present was obtained. The insecticides studied included aldrin, chlordan, DDD, DDT, dieldrin, benzenehexachlorimide, and methoxychlor.

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Metallic Ions

Many modifications of the EDTA volumetric method for the determination of total calcium and magnesium or the determination of the individual ions have been proposed. However, to date, the proposed indicators have not proven too successful. Goldstein (9) used glyoxal bis-(2-hydroxy anil) in an alkaline solution for the determination of calcium. The method was based on the fact that the red color of the calcium complex was destroyed by EDTA titration, the color changing sharply from pink to yellow.

Of the many methods used for the determination of zinc the use of "Zincon" has shown the most promise. However, a serious drawback to its use has been its reactivity with other metal ions. Platte and Marcy (24) complexed the heavy metal ions (including zinc) just as the cyanides, and then freed the zinc by the addition of chloral hydrate followed by complexing with Zincon at pH 9.0. The resultant color was measured at 620 mμ. The addition of 1.0 mg/l of zinc to various waters and wastewaters gave a maximum recovery error of 4 per cent. At lower concentration (0.1

mg/l) the error was 10 per cent. Interference by manganese was eliminated by the addition of ascorbic acid.

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Miscellaneous Papers

An appreciable amount of research has been carried out on the determination of suspended matter in wastewaters. Numerous methods have been proposed to replace the Gooch crucible procedure. Krawczyk and Gonglewski (16) carried out a comparison of the Gooch method with a photometric procedure. This latter method consisted of blending the sample for 90 sec to obtain a uniform particle size. The effect of color interference was eliminated by using a spectrophotometer in place of a filter photometer. The concentration range of suspended solids varied between 20 and 480 mg/l. These authors found that a semilog plot of transmittancy vs. suspended solids yielded a straight line. A comparison of the two methods showed that the precision obtained by the spectrophotometer was better than by the Gooch method. The standard deviation of replicate sample means ranged from 3 to 8 mg/l for the Gooch method and 1 to 5 mg/l for the photometric method.

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SEWAGE

Physical and Chemical Methods

Plant scale experiments on sedimentation and preaeration at the Los Angeles Hyperion plant were reported on by Theroux and Betz (134). In one set of experiments it was determined that increasing the effluent weir loading from 40,000 to about 70,000 gpd/ft had no significant effect on the suspended solids removal. Whenever the rate of flow through a tank exceeds 38 mgd (which corresponds to a flow-through velocity of about 4 fpm) the amount of settleable solids in the effluent rises sharply, indicating that resuspension of bottom sludge takes place at velocities in excess of 4 fpm. Data obtained by operating one battery of primary tanks without preaeration and one battery with 25 min of preaeration indicated that the preaeration did not improve removal of either settleable solids, suspended solids, or BOD, or reduce chlorine demand. There was, however, some improvement in sulfide and grease removals. Rankin (105) pointed out that there is no evidence in published operating records of numerous plants to indicate that effluent weir rates have any influence on primary tank effluents.

The effect of inlet design on the hydraulic characteristics of settling tanks was studied by Mau (71). He made model studies of the effect of various vertical-slotted inlet baffles on the flow-through characteristics. He concluded that single baffles with vertical slots would have limited application in sanitary engineering because the slot widths required for effective action would be too small. However, when using two inlet baffles, effective flow distribution could be obtained with

much lower slot velocities and hence much greater slot widths. A minimum velocity of 0.1 fps through the slots in the first baffle appeared to be satisfactory. The data indicated that the solid portions of the second baffle need be only slightly wider than the slots in the first one. A distance of 0.3 to 0.5 ft between the baffles was satisfactory for a range in slot velocities of 0.10 to 0.52 fps.

An unusual process for sewage treatment was discussed by Mendia and Buonincontro (78). The process is intended for a sewage which is to be discharged into the sea and for which disinfection and clarification rather than BOD removal are required. The sewage is screened and mixed with sea water. The mixture passes through an electrolytic cell similar to those employed in the production of hypochlorites. It has horizontal electrodes (a lower graphite anode and an upper cathode made of iron). By subjecting the mixture of sea water and sewage to electrolysis, chlorine and hydroxides are released at the electrodes. The chlorine provides disinfection and magnesium hydroxide is formed to provide a flocculation process. Following the electrolytic cell the mixture is flocculated and settled, the effluent being clear and disinfected. The sludge is carried onto drying beds without digestion.

Biological Filtration

In an effort to provide adequate sewage treatment for the increased loadings resulting from the recent expansion of housing and trade, Lumb and Eastwood (69) in England, investigated the recirculation principles involved in the filtration of settled sewage. This work was divided into two parts. The first was a study of the effects of recirculating effluent from the same filter, effluent from another filter, and effluent from a "Simplex" aeration plant. The second part was a study of the effects of the rate of recirculation when varied directly as the rate of sewage inflow, inversely with the inflow, or at a constant rate.

It was found that diluting the settled sewage fed to a trickling filter with purified effluent from the aeration plant enabled the filter to handle over twice the sewage loading normally applied and produce an effluent of better quality than normally expected from conventionally loaded filters. The single exception was a reduction of the amount of oxidized nitrogen produced.

It was concluded from the second part of the study that the best results were obtained when the rate of recirculation was directly proportional to the incoming flow. Slightly inferior results were obtained where the rate of recirculation was held constant and severe ponding, which led to a discontinuance of the test, was observed when the rate of recirculation and the incoming flow were inversely proportional.

The results of experimental work to determine the use of high-rate filtration techniques as applied to double filtration, the effect of a smaller filter media stone, and greater filter depths were reported by Meltzer (77). The work, carried out on pilot-plant scale, utilized the highly industrial sewage received at Klipspruit, South Africa. A settled sewage was applied to 6 primary filters, 6 ft in diameter and varying in depth from 6 to 12 ft. The filter effluent was combined, settled, and applied to 8 secondary filters, also 6 ft in diameter and of varying depths. When the primary filters were loaded at an equal rate per unit volume of filter medium it was concluded that the effluents obtained from filters filled with 2- and 4-in. stone were indistinguishable and the 9- and 12-ft filters produced similar effluents which were only slightly better than that from the 6-ft filters. The results obtained from the secondary filters indicated that greatly improved effluents,

especially in nitrate content, could be obtained by the use of ¾-in. instead of 2-in. stone and by the deeper filters. There was, however, no significant difference between the effluents from the 9- and 12-ft filters.

Rowell (110) loaded 5 laboratory scale filters with settled sewage at a rate of 220 gpd/cu yd in order to determine the effect of depth on the performance of percolating filters. These filters were made of 3-in. pyrex tubes filled with ⅜- to ¾-in. clinker to depths of 3, 4.5, 6, 7.5, and 9 ft. The results obtained indicated that "the efficiency per cubic yard is much the same whether in a deep or a shallow filter provided that the interstices of the medium can be kept open."

Using sodium chloride as a tracer Sinkoff *et al.* (122) determined the mean residence time of a liquid in laboratory scale trickling filters filled with glass and porcelain spheres. Four filters, 5 in., 8 in., 10 in., and 3 ft in diameter, were used. The 5-in. filter was filled to a depth of 4.1 ft with ½-in. glass spheres, the 8-in. filter to a depth of 4.1 ft with ¾-in. glass spheres, the 10-in. filter to a depth of 5.9 ft with 1-in. spheres, and the 3.0-ft filter filled to a depth of 9 ft with 3-in. porcelain spheres. Flow rates between the range of 1 to 200 mgd/acre were investigated. It was concluded that "the mean residence time of a clean fluid flowing through a bed of clean, loosely packed, unsaturated nonporous media, within the ranges stated herein is:

1. Inversely proportional to the 0.83 power of the hydraulic loading rate for glass spheres and to the 0.53 power for the porcelain spheres.
2. Directly proportional, to the same powers, to the specific surface.
3. Directly proportional to the 0.5 power of the kinematic viscosity for the glass spheres and to the 0.20 power for the porcelain spheres."

Bloodgood *et al.* (18) in another investigation of the factors affecting the contact time in a trickling filter reported the results of experiments which verified the theoretical equations which state that the liquid contact time on an inclined plane and a sphere is inversely proportional to the 2/3 power of the liquid application rate and directly proportional to the 5/3 power of the radius of the sphere.

In this study a number of spheres of a uniform size were suspended in a single strand. The liquid medium was applied to the top sphere and permitted to flow by gravity over the surface of each sphere in the series. The contact time was determined by dividing the weight of the liquid on the spheres at any instant by the rate of application.

To determine the effect of slime on the contact time, 96 test runs were made on an inclined plane apparatus with sewage flowing over an initially developed slime layer. It was found that slime growth on an inclined plane increased the contact time in excess of 50 per cent when the slope of the plane was 2.87 degrees and by less than 10 per cent when the slope was 45 degrees. There was no apparent relation between the weight of the slime and the length of contact time.

Rankin (104) states that trickling filter media has remained virtually unchanged for 50 years and suggests that research in this field could yield results that may justify increased loadings on both low and high rate units.

Conclusions were reached by Rhame (107) as a result of experiments on two equally loaded, identical trickling filters, one with and one without forced draft ventilation, that forced air ventilation had little effect on plant effluent quality but might be advantageous when sewage temperatures are high and if the distribution of air could be improved.

The effects of high pH on the per-

formance of a pilot-plant trickling filter were reported by Walter (139). The sewage applied consisted of about 60-per cent normal municipal sewage and 40-per cent highly alkaline textile waste with a pH varying from 7.0 to 11.0. Hydraulic loadings varied from 18 to 36 mgd/acre with the recirculation ratio kept constant at 2:1. It was concluded that BOD removals were greater when the pH range was between 8.0 and 9.0 and that the filter efficiency decreased as the pH increased. The buffering action of the filter reduced the pH of the applied waste when the pH was between 9.0 and 11.0 but had little effect on the pH above or below this range.

Husmann and Malz (48) carried out laboratory experiments with a synthetic sewage to determine the effect of temperature on the rate and degree of treatment afforded by biological filters. It was found that approximately the same degree of treatment was obtained when the temperature was maintained at the thermophilic range (55°C) as with the mesophilic range (18°C). Approximately the same amount of nitrogenous material was decomposed at the two temperature ranges but in the thermophilic filter the residual was largely ammonia as compared with nitrate-nitrite in the mesophilic filter. The rate of decomposition was greater in the thermophilic filter with about one half the thickness of biological slimes apparent.

The development and design of high-rate biological filters were discussed by Nelson and Lanquette (89). The history of the development of the high-rate process was discussed and the application of the NRC formula for the design of filters was illustrated with a number of example problems.

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Activated Sludge

A great deal of work has been reported during 1959 on the mechanics of the activated sludge process. In a study of the removal of dissolved organic matter by activated sludge, Wuhrmann and Beust (143) and Wuhrmann *et al.* (144) washed acti-

vated sludge and resuspended it in phosphate buffer. Various water-soluble organic substrates were added. The quantity of most of the substrates decreased linearly with time but the sludge had to be acclimated to aspartic acid before it was removed. The rate of removal of substrate was proportionate to the concentration of the activated sludge. When glucose was the substrate, the rate of removal was the same whether the system was rich in oxygen or whether it was anaerobic. This was not true for glutamic acid. Substrates containing ammonium ion were removed from solution more rapidly than were the same substrates without ammonium ion and the presence of ammonium ion increased the consumption of oxygen. They concluded that the removal of the dissolved organic substrates investigated was almost exclusively a physiological process. Morgan (86) reported that the synthesis of proteins in activated sludge units treating sewage was integrated with the Gibbs and the Embden-Meyerhof pathways. Urea seemed to be a better nitrogen donor than even the simplest amino acids. Most of the amino acids were oxidized in the citric acid cycle and some of the components of this cycle were then used to produce other amino acids which were incorporated into the protein synthesis.

The removal of the nutrients, nitrogen and phosphorus, from sewage is important because of the contribution of these elements to excessive growth of objectionable algae and other plants. Johnson (53) reported that 10 to 20 per cent of the influent nitrogen may be removed by primary sedimentation. Most of this nitrogen is in the organic form. Phosphorus may possibly be removed to the same degree by settling. Removal of nitrogen by the activated sludge process can best be expressed by the BOD/N removal ratio which usually varies from 7 to 21. When nutrient removal is desirable, a low ratio is advantageous. Husmann and Malz (48) studied the effect of temperature on the purification of sewage at temperatures from 20 to 50°C. Optimum purification of sewage, as measured by the permanganate oxygen consumed test, was at 30°C and they concluded that mesophilic conditions are best for activated sludge.

Studies by Kountz and Forney (60) on the metabolic energy balances in a multiple unit total oxidation system, using dry skim milk as a source of organic matter, confirmed earlier reports that total endogenous oxidation is not possible within reasonable times and sizes of treatment systems. They found that about 20 to 25 per cent of the new activated sludge produced remained unoxidized. About 58 per cent by weight of the ultimate influent oxygen demand was converted to new activated sludge in a continuous flow system and the actual endogenous loss was 2 per cent per day of the total weight of activated sludge in the system. The amount of non-oxidizable sludge accumulated per day was 0.6 per cent of the weight of the total amount of activated sludge in the system and the equilibrium weight of activated sludge in the system was 14 times the influent weight per day.

Buck and Keefer (22) isolated, in pure culture, a zoogleal organism from activated sludge which was different in many ways from *Zooglea ramigera*. The organism reduced nitrates to ammonia and nitrogen. When settled sewage was inoculated with the organism, aerated for 4 hr and settled for 0.5 hr, the reduction in BOD was comparable to that obtained with activated sludge.

The search for improved efficiency in aeration has also been important. A report of the experimental work carried out at the Northern Outfall Works of the London County Council with aeration is given by Burgess and Wood (23). Rates of aeration of clean deaerated water with three different types of diffusers (alundum tile, 6

in. × 8 in., alundum dome, 4 in., and alundum dome, 7 in.) were determined in towers (6-ft diameter and 10-ft deep). Under all rates of flow studied, the 4-in. dome gave poorer performance than the other diffusers. This was attributed to the small surface area of the 4-in. dome. At low rates of flow (1 and 1.72 cfm) air comes out of only small portions of different size diffuser dome surfaces, but the larger dome diffuser has a greater total surface. The diffusion from the alundum tiles is more regular and the bubbles are distributed over the whole surface of the diffuser. The studies included, in addition, the effect of spacing the diffusers on aeration performance. Detergents (from 0.4 up to 10 mg/l) gave decreasing rates of reaeration. Eckenfelder (32) has pointed out that, in addition to the usual factors of air flow rate, depth of submergence, temperature and tank turbulence, the rate of absorption in industrial wastes is influenced by the chemical nature of the waste. The transfer rate is generally lower in most industrial wastes than it is in water but in a few wastes, such as pharmaceutical and certain paper wastes, especially in high concentrations, the transfer rate may be higher than in water. He has presented some data on the effect of various antifoams on oxygen transfer coefficients. Phillips and Johnson (99) found that when sulfite was oxidized in an unsparged cylinder, the chemical reaction seemed to occur in a film of liquid at the interface. The absorption rate was independent of the liquid agitation and varied as the 1.5 power of the partial pressure of the oxygen. With sparging and violent agitation, the thickness of the liquid film was so reduced that most of the reaction seemed to occur in the bulk of the liquid. The transfer rate was nearly independent of the reaction velocity constant and was independent of the sulfite concentration over a wide range. The transfer rate was proportionate to the first power of the partial pressure of oxygen. Measurements of oxygen absorption by catalyzed sodium sulfite solution and by polarographic methods in KCl solutions were compared by Steel and Brierley (129). At low agitator speeds, the absorption coefficients were lower in the sulfite system whereas at high agitator speeds, the sulfite coefficients were higher than the polarographic values. The discrepancies were explained in terms of the differences in oxygen absorption mechanism in the two systems. The authors conclude that the sulfite system should not be used as a measure of the actual amount of oxygen transferred to a microbial culture. Further studies by Brierley and Steel (21) on the effects of sparger and impeller positions, filamentous mold mycelium, paper pulp, and sago pellets on the rate of oxygen absorption showed that within the range of conditions tested, the relative positions of sparger or impeller did not affect the oxygen solution rate significantly either in the presence or absence of mold. Marked reduction in the oxygen solution rate was brought about by the addition of filamentous mold (90-per cent reduction by 2-per cent dry weight of mycelium) and paper pulp (85-per cent reduction by 2-per cent dry weight). The correlations between oxygen absorption coefficients and operating variables (agitator speed, air flow rate) were altered substantially by the addition of mold or paper pulp and the practice of increasing the air flow rate to increase the rate of oxygen absorption was almost valueless in the presence of mold or pulp.

The Inka pipe aerators which originated in Sweden have been described by Geiger (36) as consisting of perforated pipe with openings 2.5 mm in diameter placed at a depth of 0.6 to 0.8 m. To avoid the formation of an unaerated circulating core, the aeration tank was divided by a longitudinal

baffle which reached neither to the tank bottom nor surface. The process has been used more than six years in Sweden and there are 15 plants in service and 6 under construction. In new plants, detention periods of less than 60 min are provided for complete treatment. Power requirements are about 0.4 kwh per kg of BOD removed.

Laboratory and plant scale experiments with the contact stabilization method of activated sludge treatment (short period sewage aeration and long period sludge reaeration) seemed to indicate a satisfactory and economical solution to the problem of providing future plant facilities for the Bergen County (N. J.) Sewer Authority. Using this method, Zablatsky, Cornish, and Adams (145) reported that the present tank capacities are sufficient to treat at least twice the amount of sewage permissible under standard aeration procedures. In 8 months' operation, average BOD reductions of more than 91 per cent were obtained with average sludge reaeration periods of 4 hr and mixed liquor aeration periods of about 1.35 hr. Simpson (120) found that the Halmur modification of the activated sludge process was able to produce more than 90-per cent removal of BOD from a sewage with a BOD of 185 mg/l. The Halmur system is a two-stage process wherein the sludge from each stage is returned to the aeration tank in which it is formed. The average aeration periods in the first and second stages were 43 and 53 min, respectively. The air supply averaged 0.86 cu ft per gallon of sewage.

McKinney (73) has described the complete mixing modification of activated sludge as a process in which the incoming wastes are completely mixed with the entire contents of the aeration tank. He reported that the most important advantage of complete mixing is its ability to take a waste of any BOD concentration and to produce an effluent of any desired BOD concentration in a single-stage tank. An approach to complete mixing, known as the "Side Flow" method, was mentioned (6).

In Germany, the Ruhr River Association has built a number of high rate activated sludge plants using step aeration. Rohde (109) reported that, in general, the aeration tanks are smaller and the air ratios less than in the United States. In heavily loaded plants the aeration period, in general, varies from 0.5 to 1.5 hr and the air ratios from 0.13 to 0.4 cu ft per gallon of sewage. In judging the different methods of operation of activated sludge plants, it is important to consider the amount of sludge production. Lindner (67) found that, in a two-stage operation, not only was there saving in the cost of construction and operation of the biological plant but that the sludge production was less than in single-stage operation. He compared the methods of computing sludge age and found that the volumetric method was simplest and most suitable. He did not regard sludge age important in terms of operating stability or efficiency but the sludge age could be correlated with the amount of sludge formed.

Stack and Conway (127) have developed a continuously fed oxygen utilometer for use in determining design data for the completely mixed activated sludge process. They report that design data in terms of the rate of oxygen uptake, oxygen demand, sludge production, and per cent BOD removal can be obtained. A comparative study of the economics of aeration methods used for activated sludge was made by Howland (45). He found that both theory and fact strongly support the claims of the proponents of mechanical or surface aeration. Low cost construction, low cost operation, and substantial freedom from maintenance difficulties were important factors in his decision. Isenberg and Heukelekian (50) have found that if

the suspended solids concentrations are kept constant when the sludge volume index is determined, only changes in the sludge density will affect the index values. They recommend the use of 1,000 to 1,500 mg/l suspended solids for greater precision. When this is done, a difference of 10 in sludge volume index values will represent difference in operation and not variations in solids concentrations.

A review of the literature by Kabler (54) reveals that the number of pathogenic enteric bacteria virus and tubercle bacilli in sewage are markedly reduced in treatment by the activated sludge process but the effluent will contain a portion of each kind of microorganism present in the raw sewage.

Observations on the effect of some industrial wastes on the activated sludge process have been reported. Mathews (70) found that phenols in concentrations up to 25 mg/l in terms of sewage flow can be nearly completely destroyed in a municipal activated sludge plant provided that process functioning is not inhibited by excessive accumulations of other toxic agents. Mixed liquor solids concentrations must be increased to provide for the increased loading and additional air must be supplied. Higher rates of return sludge are also needed if the return sludge is to be kept aerobic. Complete destruction of phenol cannot be obtained with reduced aeration periods. Stankey (128) reported that continuous discharge of a waste containing hexavalent chromium to the Fairfield, Connecticut, plant resulted in a concentration of 7 mg/l in the primary settling tank effluent. The quality of the activated sludge deteriorated and the final effluent became turbid. The removal of BOD through the plant decreased from 95 to 70 per cent. Drip trays upon which the plated castings could drain and be rinsed with a small amount of water were installed at the offending industrial plant. The subsequent removal and recovery of more than 50 per cent of the chromium at the industrial plant and neutralization of the acid waste restored the sewage treatment plant to normal operation.

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Disinfection

A critical examination of the literature since 1922 dealing with the bactericidal effects of various sewage treatment processes has been presented by Kabler (54). It is emphasized that treated effluents satisfying recommended standards may contain a large number of pathogens. Estimates of the hazards involved cannot be accurately determined at this time since the methods for demonstrating the pathogens are largely qualitative. Appropriate chlorine dosages, retention times, and residual levels must be designed to fit specific needs but generally an o-tolidine residual of 1 mg/l for 15 min yields satisfactory final effluents for enteric bacteria and 1 mg/l for 1 hr for the tubercle bacillus. Although appropriate chlorination will reduce the pathogens in the effluent below demonstrable densities, it is pointed out that better methods for enumeration of bacteria, fungi, and viruses are urgently needed.

Kelly and Sanderson (57) have used two parameters in determining the effect of various sewage treatment processes on Coxsackie and ECHO viruses: (*a*) the frequency of virus isolation from sewage and effluent samples based on inoculation into mice, monkey kidney epithelium, human amnion tissue, and HeLa cells; and (*b*) reduction in number of virus particles based on plaque counts in monkey kidney bottle cultures.

The presence of virus was shown in 90 per cent of the raw sewage samples from five different treatment plants. Primary treatment and trickling filters did not reduce the frequency of virus in the effluents but there was a reduction in the number of particles. Effluents from trickling filter plants that had been chlorinated (0.5 mg/l residual) contained viruses about a third of the time. Laboratory studies indicated that, depending on pH and temperature, residual chlorine values of 9.0 mg/l or greater with 15 min contact, or contact of 4 hr with combined chlorine values of 0.5 mg/l are necessary for inactivation of these viruses.

Using a gauze pad technique and selenite brilliant green enrichment medium, Bloom *et al.* (19) showed the presence of *Salmonella* in samples from all stages of the East Lansing sewage treatment plant, including the final effluent.

The reliability of the methods currently employed for determining the efficiency of chlorination is open to question on the basis of work by several authors. Robinson (108), using a modified swab technique consisting of alginate wool immersed in sewage for 48 hr and then incubated in selenite F broth, recovered twice as many enteric organisms as did the gauze swabs. Millhauer and Grossowicz (84)(85) have shown that recovery of bacterial survivors after chlorination is a function of the type of disinfection procedure employed and the type of nutrient media used for growth of the surviving organisms. The reactivation ratio, defined as the number of survivors on rich agar to the number on minimal agar, increases inversely with number of survivors.

A paper by Laubusch (62) includes a list of impurities in chlorine gas and an attempt to outline the gaps in present knowledge concerning the effect of these impurities on process applications. In other reports (63)(64)(65), he discusses the means of accomplishing the objectives of wastewater chlorination, interpretation of chlorine residuals, and the control of chlorination. The types and significance of chlorine residuals are also discussed by Baker (14).

The limiting influences of suspended solids and nitrogenous material on disinfection of sewage and sludge by halogens have been determined by Connell (27). Homogenization of the sludge resulted in less protection for the organisms and yielded greater disinfection efficiency with a given application of chlorine.

Mendia and Buonincontro (78) have reported on an unusual case where sewage being discharged into sea water required clarification and disinfection only. The sewage is screened, mixed with sea water, passed through an electrolytic cell, flocculated, and settled. The sludge goes directly to drying beds. The source of disinfectant (hypochlorite) is the electrolysis of the sewage-sea water mixture. The energy required in the electrolytic process did not exceed an average of 0.4 kwhr/ml of treated sewage.

An unusual approach to sewage disinfection is presented by Bodanov *et al.* (20). Because of the cost of chlorine in Russia and the unsuitability of chlorinated sewage for use as fertilizer, one of the authors proposes the use of some industrial emissions (nitrous oxides, sulfur oxide, formaldehyde, and combinations) for sewage disinfection. Tests indicated their high bactericidal property against *E. coli*, *S. typhi*, and dysentery organisms.

Sludge Digestion

Theory and Mechanism

A comprehensive review of the fundamental theories of sludge digestion and of modern sludge digestion practice was presented by Lohmeyer (68). Kabler (54) made a similar review of the effects of sewage treat-

ment processes on pathogenic microorganisms and concluded that digestion is not effective in inactivating parasite ova. He suggests that sludges be heat treated and dried 12 to 15 months before use on lawns, vegetables, or shrubs. The possibility of increased survival of pathogenic bacteria in short retention period digesters led Langeley *et al.* (61) to study the major factors of growth of *S. typhosa* during anaerobic digestion. The organism grew readily in culture media at ORP levels found in digesters and was not affected significantly by gases or by bacteriophages and antibiotics present. Furthermore, raw sewage is a potentially adequate source of food for *S. typhosa* and its failure to survive is a result of inability to compete successfully for food with the predominant *E. coli* and *Ps. fluorescens*. The mechanism of survival involves acquiring of the amino acid tryptophan, which is essential to the growth of *S. typhosa*.

Synthesis of cyanocobalamin I and vitamin B_{12}-like factors was reported by NeuJahr (90) to be stimulated by the addition of $CoCl_2 \cdot 6H_2O$. Under anaerobic conditions the effect is restricted to the initial stages (10 days at pH 5.5) of fermentation. Co^{++} inhibits organisms that consume cyanocobalamin I. $CuSO_4 \cdot 5H_2O$ likewise stimulated the synthesis during the early stages of fermentation by inhibiting consuming organisms at pH 5.5.

Keefer (55) observed the effects of mixing digested sludge with raw sludge in volatile solids ratios from 0.5 to 5.0. Gas production increased with increasing ratio and with the thoroughness of mixing. A 10-day digestion period proved satisfactory at a volatile solids ratio of 1:1. Chmielowski, Simpson, and Isaac (25) found 10 days to be the most efficient retention period in continuously mixed digesters fed daily with 3.14-per cent total solids. Data were presented which indicate that the rate of production of gas after daily feeding of a digester may give significant information on its behavior.

In studies of the effect of loading, in the range of 0.05 to 0.135 lb/day/cu ft, on the performance of digesters during a 33-day retention period, Mueller *et al.* (87) found that volatile acids, alkalinity, suspended solids in supernatant, relative quantity of butyric and propionic acid, CO_2 content of gas, and the volatile solids in digested sludge all increase with loading rate. Gas production and volatile solids destruction decrease. A critical load level exists below which change in loading has no effect. At 2,000 mg/l volatile acids, gas production is inhibited.

Jeffrey and Morgan (52) found that clear liquor drained from digested sludge may have a 20- to 40-day oxygen demand above 2,000 mg/l. More than 98 per cent of this is exerted by ammonia and nitrite oxidation. The carbonaceous demand is negligible. A lag period of 5 to 10 days is exhibited, and depends on the nature of seeding of the sample. Thus the 5-day BOD may be meaningless when used to evaluate the oxygen demand of anaerobic digester liquor.

Grune *et al.* (40) studied the effect of carrier-free I^{131} and P^{32} on an anaerobic digestion. With I^{131} up to 300 mc/l rate of gas production was not affected. At 600 mc/l, a significant reduction of the reaction velocity constant was found. Ultimate gas production, volatile acids concentration, volatile matter reduction, and pH were not significantly affected by concentrations of I^{131} up to 600 mc/l. Percentage of carbon dioxide in the gas was slightly higher.

High specific activity P^{32} up to 400 mc/l had no effect, while at 800 mc/l it had a significant effect on the reaction velocity constant. Ultimate gas production was not affected up to 100 mc/l of P^{32}, but above this value it was significantly reduced. Volatile matter reduction was affected to some

degree and volatile acid concentration at the end of digestion increased materially in the presence of P^{32}. Above 100 mc/l, percentage of CO_2 progressively increased with increasing concentration of P^{32}.

These findings are in disagreement with results of previous studies with P^{32} when high concentrations of carrier salt were used.

New Developments

Schroepfer and Ziemke (115)(116) reported the successful application of an anaerobic contact process to packing plant, wood fiber, and synthetic milk wastes. The process involves two phases: (*a*) anaerobic sludge in contact with wastes to adsorb and stabilize nutrients present, and (*b*) separation of liquor from sludge. Through procedures described by the authors the process is capable of removing 80 to 90 per cent of the 5-day BOD of the wastes at 0.10 to 0.20 lb/day/cu ft loadings, at 35°C, or 0.05 to 0.10 lb/day/cu ft, at 25°C. A sludge concentration of 12,000 mg/l is utilized and a 10°C temperature variation is the maximum permissible. Tank surface overflow rates range from 150 to 300 gpd/sq ft, based on raw waste, or from 400 to 800 gpd/sq ft, based on total outflow.

Vahidi (138) applied anaerobic digestion to waterworks sludge to improve the recovery of alum. Gas adsorption chromatography was used (25) to analyze gas from experimental digesters. The equipment involved a Sr^{90} beta radiation ionization chamber with argon as the carrier gas.

Latest recommended procedures to improve digester performance were reported by Gould (38) to (*a*) maintain 90°F temperature, (*b*) keep alkalinity at 2,000 mg/l, (*c*) thicken raw sludge to 10 per cent, (*d*) feed raw sludge continuously, (*e*) circulate digester contents, and (*f*) prevent sludge and scum accumulations. This permits raw solids loadings up to 3 times normal, or 8 lb/cu ft/month. At the Nut Island plant 2-in. nozzles discharging supernatant at a total of 1,000 gpm are used effectively to break scum in a 108-ft diameter digester.

Schreiber (114) considered the problem of increasing capacity of digesters without increasing size. Reported successful loadings of 530 lb/day/1,000 cu ft are about twice that presently specified by the District of Columbia Board. Use of thickening tanks to get rid of supernatant and of continuous gas recirculation for scum control is among the developments which make possible increased loading. Plant scale operating data were presented by Nelson and Budd (88) to show that thickening of sludge ahead of digestion is practical and economical, and indicative of the feasibility of higher rates of digestion. Torpey (135) developed a thickener which concentrates sludge to 9- to 14-per cent solids in a short time.

Hindin and Dunstan (42) concluded on the basis of laboratory work that the use of thickened sludge or decreasing the time of digestion should be practiced with discretion. Detention time not much less than 30 days and loadings in the range of 0.075 to 0.10 lb of volatile matter per cubic foot of digester capacity were recommended for single stage digesters.

Studies by Blodgett (17) on a pilot scale showed that 25 to 50 per cent of the solids from a high rate digester can be directly incinerated without added fuel. A nozzle is described (8) which enables the operator to break scum in a small digester in half the 20 to 30 hr formerly required.

Maintenance and Operation

Successful starting of a 50- by 19-ft digester in 16 days was described by Hicks (41). Twelve feet of water and 500 lb of lime were introduced and heated to 90°F. Raw sludge was then added for two 10-min periods each day for one week and recirculated 6

hr each day. During the second week sludge was added for two 20-min periods daily. On the 16th day gas was available to fire the boiler. Normal mixing for three 2-hr periods and sludge recirculation for one 4-hr period each day were then resumed. At Tarrytown, similar results were observed by Orford *et al.* (93). The digester was filled with sewage and heated to 90°F, the full load of 400 cu ft/day was then added with lime to maintain a pH of 7 to 7.2. Sludge was recirculated from the bottom daily at 3 to 4 times the daily addition volume. After 30 days gas production started quite suddenly.

German practice was described by Annen (3). Raw sewage is heated to 30 to 33°C and thoroughly inoculated with digested sludge. Fresh sludge is then added at one-tenth the normal rate in terms of volatile solids. When methane production is established, the rate is doubled. The first gas is 60-per cent CO_2. This declines to 39 per cent with good operation, although it may rise to 90 per cent with poor operation. Fatty acids should remain under 300 mg/l. If over 4,000 mg/l the tank must be drained and restarted. Between 300 and 4,000 mg/l, lime may be used to restore proper acid content. No fresh solids are added with the lime until methane production is restored.

Control of pH was found by Cassell and Sawyer (24) to be the most important practical factor in starting a high-rate digester. In studies of the problem of developing normal digestion in a high-rate tank receiving all the sludge from a primary plant, successful starting was accomplished on a 20-day retention schedule at volatile solids loadings up to 0.162 lb/day/cu ft when the pH was maintained at 6.8 to 7.2. Without pH control, however, even at a 30-day retention period and a load of but 0.045 lb/day/cu ft, successful starting was not accomplished. Under the pH controlled, 20-day retention conditions, 40, 50, and 65 days were required for normal digestion to develop at loadings of 0.054, 0.018, and 0.162 lb/day/cu ft, respectively.

Sperry (125)(126) studied the comparative gas production in a digester operated with standard gas recirculating equipment, and in one without such mixing. Gas production in the former averaged 16.3 cu ft/lb volatiles destroyed, whereas the latter produced but 12.4 cu ft/lb. The use of gas recirculation for scum control was found by Barrett (15) to be of doubtful value. In digesters requiring annual removal of scum up to 12.5 ft in thickness, gas recirculation cost 4 times that of cleaning by pumping down the digester. For such pumping down, a water-operated ejector connected to the suction side of the pump was found (7) to make possible the complete cleaning of a 110-ft diameter digester in two weeks.

Rotation of the contents of a digester by tangential flow of incoming sludge was found (17) to reduce 4 to 5 ft of scum to 1 ft in 48 hr. At Ontario, Canada, a digester equipped with two draft tube mixers was reported (41) to have developed only 12 in. of scum, and accumulated but 2 cu yd of grit in 6 years of continuous service. Other operators reported (6) difficulties in digesting skimmings and in pumping sludge at 11.5-per cent solids.

Continued difficulties in handling skimmings and grease were reported. At Wichita, Kansas, where the ratio of household garbage grinders is 1 per 12 persons, Lee (66) described typical difficulties. Skimmings collected by use of 0.17 cu ft air/gal are pumped to a digester where they are satisfactorily digested. To keep the pump discharge lines clean a weekly backflush with 25,000 gal of warm supernatant is used. On occasion it is necessary to use caustic. At such times, 250 lb of flake caustic are used in 450 ft of 6-in. line. After 12 hr

detention this is flushed with warm supernatant into 100,000 gal of sewage. At Minneapolis the practice, as reported by Mick (82), is to pump grease to a lagoon. This grease is 98 per cent combustible and has a heat value of 13,000 Btu/lb. It contains 78-per cent fats and 10-per cent mineral oil. Once a year the lagoon is ignited and the collected grease burned. Miller (83) reported that 6- to 8-ft scum layers in digesters at Norfolk, Virginia, are 20-per cent grease. No satisfactory equipment has been developed for the handling of grease and skimmings. Grease balls appear in pump sumps at 35 stations, but it is not known whether they form in sewer lines or directly in the pump sumps. Grease balls 15 in. in diameter were reported (82) in the preaeration tanks at Wichita.

The properties of digester supernatants and various methods of treatment are discussed by Howe (43).

Design

Little information on design appeared in the literature. Digesters designed for sludge inlet or outlet at any one or combination of 15 locations were reported (6). Pilot studies of grease incinerators (82) yielded a tentative design burning rate of 0.4 cu ft/hr/sq ft of liquid surface. Need for a digester design which allows removal of scum not digested was noted (38).

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Sludge, Disposal and Utilization

Sludge Concentration, Conditioning, and Disposal

The Zimmermann Process for wet oxidation of sewage sludge has been reviewed by a committee (26). Additional data and information are contained in the results of a year-long 2-ton pilot-plant study to determine the feasibility of utilizing the process for disposal of 200 to 250 tons of solids from the Chicago plant (11). Basically, operation consists of preheating the sludge to 180°F and then to a final temperature of 515°F at 1,200 psi after passage through 3 heat exchangers. The oxidized sludge is cooled to 150°F and the ash is separated and pumped to a lagoon. It was found that to be thermally sufficient, the sludge should supply approximately 2,350 to 3,000 Btu per gal. This would necessitate a solids concentration of 3 per cent. For the reaction to be self-sustaining, 5-per cent solids are required. Primary sludge was easily concentrated but experience has shown that without chemicals it was not possible to concentrate activated sludge above 3 to 3.5 per cent by gravity methods. Laboratory experiments on dissolved air flotation gave good results but could not be repeated on the pilot size unit. Vibrating screens gave too low a yield, although the solids concentration was sufficient. Centrifuging, capable of producing 5- to 12-per cent solids with adequate yields, looks promising. The effectiveness of wet oxidation, as measured by COD, showed a rather constant reduction of 80-per cent total solids and 87-per cent volatiles.

Further data and evaluation of the process were given by Zimmermann (146). The effect of temperature, pressure, and heat content of the waste is detailed. Based on pilot-plant studies, construction costs will range about $50,000 and $25,000 per ton dry solids for 5- and 100-ton capacity plants, respectively. Operating costs ranging from $6.30 to $14.80 per dry ton of solids processed can be expected.

Pinder and Gauvin (100) (101) have reported on pilot-plant studies utilizing the principle of atomized suspension for pyrolysis of sewage sludge. The pilot plant was set up to handle primary sludge at 5- to 6-per cent solids in amounts equivalent to a population

of 10,000. The units are simple and compact, consisting of a cyclone evaporator at 1,500°F for sludge concentration and a reactor at 1,400°F in which combustion of the sludge, which has been atomized through nozzles at a pressure of 40 psi, occurs. Limited results indicate that the equipment can be made fully automatic and that thermal self-sufficiency can only be attained with a raw sludge concentration of 14 per cent. A complete cycle from the introduction of the sludge to the formation of ash, steam condensate, and flue gas is approximately 15 sec. This process may be highly applicable to small plants because of its low capital cost, flexibility of operation in producing either a dried or ashed residue, reuse of energy contained in the steam, and low operating costs. At present, fuel demands constitute the largest cost item.

Owen (94) has discussed the construction and operational features of the Herreshoff multihearth sludge burning and heating furnaces. The cost factors are analyzed from the bases of the physical and chemical characteristics of the sludge, labor, and maintenance. A new installation in Ohio will use the exhaust gases from a refuse incinerator, at 1,400°F, to burn 6,200 lb/hr of undigested sewage sludge at an estimated cost of $10 per ton dry solids.

Frazee (35) has discussed the problems encountered at Camden, New Jersey, in the filtration and incineration of primary raw sludge. Filtration is handled by 6 drum-type filters with 120-x 46-mesh Saran cloth. Drying and incineration are accomplished by a 2 flash-drying and incinerating units rated at 10,000 lb/hr at 70-per cent moisture. Design heat content of the cake was 5,200 Btu per lb with a volatile content of 52 per cent. Auxiliary heat is furnished by oil burners. Difficulties encountered but eventually solved were primarily those concerned with maintaining the units at rated capacity for maximum efficiency. Tannery wastes would peel off the filters, resulting in slug loadings to the incinerators followed by periods of zero load. The drying units were also affected. High Btu content necessitated installation of water sprays to prevent excessive temperatures. Material of asphaltic nature caused buildup and braking of the cage mill. Problems associated with filter "blinding" and operational procedures for maximum efficiency have been resolved. Detailed data are given for the efficiencies and loadings of the units. Total operating costs for the year were $36,307 for filtration and $26,028 for incineration, corresponding to $27.29 per ton of dry solids, $12.40 of which was for filtration and $8.89 for incineration.

Arven (13) has described the sludge conditioning, filtering, and incinerating practices at Dearborn, Michigan. In conditioning, use is made of waste steel pickle liquor as a substitute for ferric chloride. The cost of the pickle liquor and lime is 1¼¢ per ton of sludge conditioned. Use of nylon as a filter media has been found to be highly advantageous from the standpoint of costs and efficiencies. Incineration has handled about 51 tons per day containing an average of 65-per cent moisture during the past 10 yr at a total cost of $2.04 per wet ton.

Pettit (98) has outlined the operation and advantages of incinerating raw sludge at Barberton, Ohio. A multiple-hearth incinerator was installed in 1937 in place of overloaded sludge-drying beds which were creating odor and fly nuisances. The cost of incineration, inclusive of gas, power, labor, and maintenance, was estimated at $5.36 per ton dry solids for the 6-yr period 1949 to 1955.

Research in methods of sludge dewatering other than vacuum filtration was actively pursued. The Wupper Sanitary District in Wuppertal-Buchenhofen, Germany, has completed ini-

tial pilot-plant studies utilizing sonic screens for sludge dewatering (58). The dewatering mechanism results from longitudinal and transverse electromagnetic vibrations in the sonic range. The transverse waves produce an extremely rapid dewatering rate while the longitudinal waves move, agglomerate, and concentrate the solids. The basic units consist of a coarse screen, 8-x 24-mm mesh, a sonic wet screen, sonic filters, 0.5 to 0.1 mm, and a roll press. The factors affecting dewatering were dependent on the loading, particle size, angle of sludge discharge, and size of filter mesh. Typical solids removal were 2 per cent for the coarse screen, 23 per cent for the 1.5-mm sonic screen, and an additional 55 per cent with subsequent sonic filters in series. The discharged sludge had a moisture content of 75 to 80 per cent which was reduced to 60 to 65 per cent by the roll press. The filtrates from the sonic filters varied from 5- to 20-per cent solids corresponding to an over-all solids removal of 80- to 95-per cent solids. In addition, the filtrate had excellent settling properties which would be expected to assist in primary sedimentation of the raw sewage. The capacity of the unit is dependent on the number of sonic filters used but averages about 35 cu ft of 10-per cent sludge per hour per filter. Power, labor, and maintenance costs are low. The investment for a population of 100,000 would be approximately $20,000 with operating costs of $0.15/cu m sludge. A complete analysis and removal efficiency for various particle sizes are given.

Laboratory experiments to effect a concentration of sludge by means of dissolved air flotation were described by Hurwitz and Katz (47). It was possible to concentrate activated sludge to an average of 5- to 6-per cent solids with a 2-hr detention time and a recycle rate of 200 per cent. (Recycle rate is the volume of air-charged stream per unit volume of sludge.) Primary sludge was concentrated to an average of 10.75 per cent and mixtures of activated and primary sludges gave intermediate values. In general, factors affecting the final sludge concentration are the nature of the sludge, recycle ratio, and time. Limited data prevented the establishment of any firm relationship among the variables.

White (141) has reported on the use of an 18- × 28-in. continuous centrifugal filter to handle digested sludge at Daly City, California. The feed sludge averages 7.0- to 8.0-per cent solids. At 1,900 rpm or 935 times gravity, the dewatered sludge averaged 30- to 35-per cent solids, while the filtrate contained 1.5- to 2.5-per cent solids. Approximately 9 cu yd of sludge are produced per week which is used by the city and private home owners as a soil conditioner.

Increased interest in dewatering of raw sludge was evident this year. Trubnick (136) briefly reviewed some of the factors affecting vacuum filtration and presented data on filtration of raw sludge. Results indicate that beyond an effective open area of 5 per cent, there is no improvement in efficiency as a function of size of openings. Although costs of vacuum filtration may vary from $7.39 to $12.75 per ton dry solids for digested sludge, the cost of chemicals usually represents 50 per cent of the total cost. Performance data on 9 plants dewatering raw sludge compares favorably in cost and efficiencies with those of digested sludge dewatering. At a pH of 12, coliforms are highly reduced, varying from 0 to 2.4×10^4 per dry gram. Regrowth is negligible. The author concludes that vacuum filtration of raw sludge meets with requirements of low installation costs, economical operating costs, minimum area, absence of nuisance, and a disposable end-product.

Komline (59) has obtained a patent on filtration of undigested sewage sludge. The sludge is to be treated

with calcium hydroxide and filtered. It is claimed that 80 to 90 per cent of the fine particles are retained and that the rate of filtration is improved over conventional methods.

Dietz and Clinebell (30) reported on the results of a questionnaire survey from and visits to 24 plants located in Illinois, Tennessee, Wisconsin, and Indiana. A first and annual cost analysis for sludge treatment facilities indicated that with 25,000 population, vacuum filtration of raw sludge is more economical than digestion followed by sand drying beds. Of the 24 plants, 50 per cent were filtering raw sludge. Costs per ton ranged from $8.20 to $32.40, with a mean of $19.90. Final disposal practices were almost equally distributed among incineration, stockpiling at the plant, land fill, and for farm or landscaping use. Operational problems encountered in the use of vacuum filters are given.

Nelson and Budd (88) have reviewed pilot- and full-plant results on sludge thickening, high rate digestion, and dewatering. Results for vacuum filtration are limited mainly to synthetic fabric media, including Dacron, Saran, Polymar, and polyethylene.

Singleton (121) has described the operation and maintenance of a coil filter treating 100,000 gpd chemically precipitated sludge containing a high proportion of paper mill wastes. The presence of the industrial waste has a tendency to reduce the efficiencies of dewatering. The agglomerating properties of the sludge are enhanced by recirculation of sludge in the secondary digester by pumping to the top and allowing the sludge to resettle. This results in a favorable chemical composition of the sludge relative to alkalinity, pH, volatile acids, and gas make-up. A 12-per cent lime dosage gives a cake equal to that of a lower lime dosage and ferric chloride. The average filter yield is 5 lb/hr/sq ft, 68-per cent cake moisture, at a total cost of $5.41 per ton dry solids filtered. Operational efficiency has been improved by a 45-min thorough washing of the coil filter after 7 to 8 hr of operation, and when a longer shutdown period is possible, a thorough cleansing with HCl for removal of lime scale is practiced.

Anderson (2) has described the effect of textile and brewery wastes on digestion and vacuum filtration of sludge at the Cranston, Rhode Island, sewage treatment plant. Prior to the introduction of the waste, using a rotary drum vacuum filter with a wool blanket, the filtration rate with a feed solids of 6 per cent was 5 psf/hr with a ferric chloride dosage of 3.5 per cent. Introduction of brewery wastes decreased the yield to less than 3 psf/hr with a 6-per cent ferric chloride dosage and these rates were lowered with the introduction of textile wastes. In 1949, both these wastes were prohibited from the plant and although the filtration rates improved, poor digestion prevented maximum efficiency of the filter. Elutriation improved performance appreciably. When textile wastes were re-admitted in 1954 (1.56 mgd or 34 per cent of the total monthly plant flow) experiments were undertaken to improve filtration. Dacron cloth plus the installation of a string discharge mechanism was highly beneficial but better improvements were obtained with the installation of a different unit. The new filter averaged 40,000 lb per 8-hr run or 3.05 psf/hr. It is expected that this can be increased to 4 psf/hr as compared to 3 psf/hr for the string filter but this is still less than was produced in 1956.

The sludge handling procedures at the Minneapolis-St. Paul, Minnesota, plant have been described (9). Use of Saran cloth has proved more efficient than Canton flannel in relation to economy and "blinding" difficulties. Average Saran life was 9,329 hr as compared with 433 hr for flannel cloth used in 1954. Savings in cost of iron and lime have been realized by pur-

chasing waste ferric chloride and carbide lime slurries. At Winnipeg, Manitoba, (9) digested sludge in excess of the capacity of one 10- × 10-ft vacuum filter is discharged to lagoons. At South Bend, Indiana (9), 80 per cent of the digested sludge was deposited on farms, parks, and playgrounds. At the Middlesex County, New Jersey, treatment plant (9), chemically precipitated sludge is thickened in tanks from 0.5- to 6.5-per cent solids and disposed of by barging to sea.

Corpus Christi, Texas, (12) has installed rotary dryers for handling digested sludge. Dried sludge is mixed with filtered sludge and fed across the entire cross-section of the rotary shell by lifters which shower the sludge through the rotary hot gas stream. Sludge is protected from overheating by mixing the flue gas with excess air prior to admission to the wet sludge mixture. Thus, the hottest gases meet the wettest material and overheating is prevented. The product is granular, non-dusty and the off-gases are rendered odorless by maintaining a minimum temperature of 1,200°F.

Eastwood (31) has concluded from the results of laboratory experiments that an empirical test, "cracking time" (the time taken for a sludge cake to crack in the Buchner funnel under vacuum) is as good a measure as the specific resistance concept which is based on a systematic and logical expression of filterability. It was found that neither of the two tests were quantitatively related to results obtained under full-scale pressing practices. Although it was admitted that the concept of specific resistance may be more applicable to full-scale vacuum filtration practices than to pressing, it was felt that next to small-scale sludge pressing experiments, the use of the "cracking time" was to be preferred because of its simplicity and ease of determination.

Laboratory experiments on drainage of digested sludges conditioned with aluminum chlorohydrate were reported by Templeton (133). Three cubic feet of sludge were applied to a depth of 9 in. and at the end of 36 days, the treated sludge gave up 10.01 gal (53.33 per cent) and an untreated sludge 4.04 gal (21.50 per cent) of the initial water. The treated sludge drained at a more rapid and more regular rate than the untreated, but after 15 days the rates for both sludges were similar. In studies of the effect of evaporation it was concluded that the final moisture content is largely dependent on evaporation which may be of greater importance than the moisture loss due to drainage.

There were three papers which described the practice of sludge disposal at sea. Baxter (16) gave an excellent presentation of the bases for selection of the proposed sludge disposal practices for Philadelphia. In an effort to arrive at the most feasible project from the standpoint of economics, current and future needs, changes and advances in methods of sewage treatment, health and aesthetic considerations, and future land use, no less than 14 methods and combinations of sludge disposal were thoroughly assessed. The accepted scheme, which will serve the 3 Philadelphia plants, producing an estimated 223,000 tons of 10-per cent sludge in 1965, was barging to sea from the Northeast plant. The proposed disposal site for the digested sludge is to be 11 nautical miles at sea from the mouth of Delaware Bay, at a total distance of 97 nautical miles from the plant. The construction costs are estimated at $1,379,000 and $195,000 for annual operation of a 4,000-ton barge, or $8.78 per ton of dry solids.

The sludge disposal practices of the 12 treatment plants in New York treating 901.5 mgd were described and evaluated on the basis of economy and flexibility of operation by O'Leary (91). In 1957, sludge equivalent to

91,000 tons of dry solids was barged to sea and dumped at a point 8 nautical miles from shore by 4 diesel-powered vessels. In addition, 5 to 10 per cent of the digested sludge produced is being conveyed to 1,700 acres of existing and proposed park areas as topsoil. The advantages of sea disposal are relatively low cost, $13.70 per ton dry solids including depreciation, interest, salaries, supplies and maintenance; freedom from nuisance, elasticity of operation, complete disposal, including present attempts to remove unwashed grit to sea. It is planned to deliver digested sludge from the vessel now under construction to shore areas for drying and use as topsoil. The major disadvantage to date has been odor production during loading of raw sludge at Wards Island which produces 45,000 tons of sludge per year. Activated carbon and ozone have been used to alleviate this problem but the results have not been entirely satisfactory.

Due to the high cost of dewatering ($14.22) per ton and the escape of 68 tons of solids per day via a one-mile ocean outfall, the Los Angeles Hyperion treatment plant constructed a 7-mile, 21-in. sludge outfall at a cost of $2,719,706 (46). Prior to construction, detailed studies on oceanographic factors, including currents, convergence systems, temperature, and biology of bottom fauna were made. As a result of these analyses, the outfall was placed at a depth of 320 ft in order that the sludge would remain submerged. During one year of operation, studies costing $100,000 have been in progress on changes in bottom life, bottom solids accumulations, bacteriological, and floatable solids. Installation of the 7-mile outfall has alleviated conditions of the present 1-mile effluent outfall but investigations are continuing in an effort to reduce and remove the amount of floatables in the sludge. The pipeline is provided with cathodic protection but cleaning is now indicated. Present costs of disposal are $1.15 per ton.

Griffin (39) has compared the costs of sludge disposal at the New Rochelle, New York, plant, which employs incineration; and the planned Joint Plant in Yonkers where barging is contemplated. The annual total disposal costs per ton of dry solids at New Rochelle based on 925 tons per yr is $62.02 which can be reduced to $36.28 at the maximum capacity of the units of 3,000 tons per year. The latter cost figures represent $13.50 for interest and depreciation on capital costs for the building, vacuum filter, and incinerator; and operating costs of $12.72 for filtration and $10.06 for incineration. The Yonkers plant, based on 8,850 tons dry solids per yr (1980) will cost $16.05 per ton dry solids representing $2.98 for interest and depreciation of capital costs for a 1,600-ton capacity barge and dock; $5.99 for barge operation and maintenance, and $7.08 for barge towing.

Sludge Utilization

Merz (80) reported on studies initiated in 1955 on primary treatment in an attempt to decrease the cost of sludge disposal and to increase the agricultural value of existing sites. A 4-acre sandy plot was prepared, diked, and loaded with sludge from 10 to 100 tons dry solids per acre. Control areas were virgin soil and soil to which ammonium sulfate only at 40 lb nitrogen per acre, was added. The effects of the sludge on the soil after 3 months of application were as follows: (*a*) increase in percolation rate, moisture content, and conductivity, (*b*) approximately doubling of the organic content, (*c*) increasing pH with high sludge loadings, (*d*) no increase in boron, and (*e*) no undesirable anaerobic conditions as determined by BOD and odors. The results of a 144-day growing period for barley indicated that all sludge applications improved the yield over the no loading

area; 50 tons of sludge per acre loading gave the greatest yield, other higher loadings gave varying results, and ammonium sulfate plots gave varying yields. Preparation of the site for a second planting in 1957 indicated that there was a residual beneficial effect of the first sludge additions and no detrimental effect at the highest loadings. The main problem encountered was the increased salinity resulting from the liquid portion of the sludge. This problem could be eased with ample and judicious irrigation practices. Flies were predominant prior to sludge drying. There was no detrimental effect on surrounding well waters. The total cost of applying the sludge at 6.48-per cent solids was $23.03 per ton dry solids as compared to $39.15 in 1953–54 during normal plant operation of elutriation and vacuum filtration.

Anderson (1) has reviewed the use and limitations of sewage sludge as a fertilizer. The nitrogen content and quality essentially fix its value. Since sewage sludge is high in organic matter it may find a market as an organic ammonia in competition with certain seed meals and pomaces. Since the nitrogen content of activated sludge is 2.5 times that of digested sludge and the nitrification rate also 2.5 times, the former may be considered 6.25 times more "valuable" than the latter. During the past 20 yr the nitrogen content of activated sludge has remained constant, about 6.0 per cent while the P_2O_5 content has increased from 3.2 to 5.7 per cent, due primarily to detergents, ground bones, and garbage additions. From 1930 to 1957, the tons of dried activated sludge used as fertilizer has increased from 14,852 to 93,152 and from 17,811 to 55,965 in 1950 as a mixed fertilizer. The corresponding figures for dried digested sludge is 23,000 to 37,577 and 3,000 to 6,581. The demand for organic ammoniates is influenced by a number of factors including forms of chemical nitrogen, higher analysis mixed fertilizers, and use as animal feed. Although the use of activated sludge for direct application to land is increasing, the nitrogen contained in the sludge sells at a much higher cost than chemical nitrogen. Unless the price is reduced, sludges as fertilizers will probably find but limited use at the points of production.

Fleming (33)(34) has compiled the methods of sludge disposal of 28 southeastern cities in Alabama, Florida, Kentucky, South Carolina, Arkansas, and Tennessee. The predominant practice is to digest, condition, vacuum filter, and apply to drying beds. Most common practice in 10 towns and cities in Tennessee for sludge disposal is to give it to farmers in dried cake form and one plant disposes of its liquid sludge for agricultural use. Two plants are conditioning and filtering raw sludge and disposing of the filtered product on agricultural lands. Although the sale of air-dried sludge, as a whole, is increasing, the demand is not great enough to defray the cost nor to utilize all the sludge produced.

Composting

Jaag (51) has presented a review of composting techniques including a detailed discussion of experiments carried out during the past few years at the Institute of Zurich on joint processing and composting of garbage and sewage sludge. Results have indicated that the total amount of garbage and sludge of a community can be processed by use of the DANO Biostabilizer method if the average water content of the wastes are 30 per cent and 70 to 75 per cent, respectively, and the ratio is 0.31 sludge to 500 garbage. The importance of stack height, ventilation, temperature, moisture, and sludge porosity in the composting process are discussed. The need to assess the composting process in relation to economics, technology, soil-enrichment,

and prevention of pollution is believed to be of such a scope as to demand international cooperation.

Schulze (118) presented laboratory experimental results on composting of a synthetic garbage in a rotating lucite apparatus simultating conditions in a compost pile. Results indicated that during the course of complete aerobic decomposition, which averaged 14 days, the pH increased from 5.2 to 8.8, the C/N decreased from 28.6 to 19.9, 40.1 per cent volatile matter was destroyed, and moisture remained constant or increased slightly. Oxygen consumption increased with increasing temperature, and between 80°F and 146°F, the increase was linear with a Q_{10} of 1.9. The oxygen uptake rates in the linear range were from 1 to 5 mg per gram initial volatile matter or 9 to 29 cu ft per pound volatile matter.

Reeves (106) has reported on initial studies of survival of *Salmonella* and *Shigella* from windrow composting of sewage sludge and sawdust at the sewage treatment plant of the City of El Paso, Texas. The sludge to be composted was combined primary and secondary which had been digested for a period of 45 to 90 days, followed by 4 to 6 months on drying beds. Composting required 2 to 3 months followed by grinding and storage in piles for an additional 2 to 3 months. Samples were collected at 10- to 14-day intervals over a period of 4 months at depths varying from 1 to 24 in. Sixty-one strains of *Salmonella* and 12 strains of *Shigella* were isolated at all depths but there was no correlation between the numbers isolated and moisture, ambient temperature, coliform, or total plate count.

In an effort to solve the problem of lack of sludge drying bed capacity and poor drying, Santa Rosa, California (76), has initiated drying studies on a "sludge" composed of sewage sludge, wood-shavings, and street sweepings. To date, the capacity of the beds has been doubled without the necessity of cleaning. Although the sludge does not represent a composted material, it is felt that with increased detention time this will be achieved.

Peel (96) discussed the need for improving food production in tropical Africa in view of the increasing population and stresses the utilization and value of composting for this purpose. If proper organization and supervision are maintained, there is no health hazard.

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Detergents

Spargo (124) determined the concentration of anionic detergents in raw sewage and the effluents of various treatment devices of the Johannesburg sewage works. He found the average concentration of detergents in raw sewage was 4.6 mg/l on active matter basis. Approximately 5 per cent of the synthetic detergent was removed by sedimentation and approximately 50 per cent of the remainder was removed by biological filtration. The activated sludge process removed 66 per cent of the detergent entering the unit. The Witwatersrand streams showed appreciable pollution by synthetic detergents.

McKinney and Symons (75) studied the biological decomposition of ABS. It was concluded that common soil and water bacteria which predominate in activated sludge can utilize ABS as their sole source of organic matter. Also, activated sludge cannot degrade ABS completely but can decompose the

basic components of the ABS molecule. The authors believe that a quaternary carbon in the hydrocarbon side chain blocks metabolism and complete degradation of the ABS.

In a second study, using 10 mg/l (active matter) of commercial ABS, in laboratory activated sludge units, McKinney and Donovan (74) concluded that conventional activated sludge systems should give up to 75 per cent reduction in ABS and the removal seems to be related to the rate of sludge synthesis.

In complete-mixing activated sludge systems, ABS reduction up to 80 per cent should be obtained. This reduction appeared to be a function of the sludge mass.

McGauhey and Klein (72) conducted a series of experiments to determine: (*a*) the ability of sewage treatment processes to remove or decompose ABS detergent, (*b*) the influence of operational variables on this ability, and (*c*) the interference by ABS with treatment processes. The authors employed ABS derived from an alkyl benzene blend which they sulfonated in the laboratory. For radiochemical work, alkyl benzene was sulfonated with S-35.

Sedimentation removed 2 to 4 per cent of the ABS in 2 hr. Complete removal of suspended solids by filtration yielded a 10- to 12-per cent removal of the detergent. In prolonged activated sludge experiments during which BOD removal was in the range of 88 to 97 per cent, ABS removal varied from 19 to 77 per cent. Greater average ABS reductions were achieved with high solids concentrations in the mixed liquor. Between 60 and 70 per cent of the ABS was removed when mixed liquor solids ranged from 5,000 to 6,000 mg/l.

A single-stage activated sludge unit with 4- to 6-hr aeration should remove 50 to 60 per cent of the influent ABS, while a two-stage plant should remove 70 to 75 per cent of the ABS. Induced foaming yielded over 80 per cent ABS removals from primary tank effluent.

Truesdale *et al.* (137) investigated, on laboratory scale, the removal of alkyl aryl sulfonate detergents by trickling filter and activated sludge processes. Three detergent formulations, (*a*) detergent B—in present usage, (*b*) detergent A-1—new ABS compound plus 20-per cent detergent B, and (*c*) detergent A-2—new ABS, were added to synthetic sewage in concentrations of 13 mg/l on active matter basis.

It was found that trickling filters removed 67 per cent of detergent B, 84 per cent of detergent A-1, and 93.7 per cent of detergent A-2. The activated sludge process during 6-hr retention period, removed 68.7 per cent of detergent B, 90.9 per cent of detergent A-1, and 93.5 per cent of detergent A-2. Foam production by the effluents from the biological processes was least with detergent A-2 and highest with detergent B.

Isaac and Jenkins (49) studied the effect of sugar-based detergents, Sucrodet D-600 and Sequol-260, on the uptake of dissolved oxygen from seed BOD dilution water. The presence of these detergents stimulated the uptake of oxygen; the stimulation increased with increasing amount of detergent added. With 10 mg/l of tetrapropylene benzene sulfonate, no significant stimulating effect was observed.

According to Polkowski *et al.* (102) a statistical analysis of laboratory and field data from activated sludge plants showed that the concentration of ABS in the aeration tank filtrates is significantly correlated with frothing. Neither the organic-N concentration nor the BOD is related. Increasing pH and temperature enhanced frothing but high electrode potentials inhibited it.

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Lagooning

Smallhorst (123) has traced the development of oxidation ponds from the earliest sewage holding ponds at San Antonio in 1901, Abilene in 1925, and the original sewage oxidation pond at College Station, in 1929, to the present day of specially designed systems. The artificially lighted oxidation pond of the San Marcos Air Force Base is described. The bacteria-algae interrelation, the effects of light, temperature, and wind on the activities of these organisms in destroying the organic materials of sewage are discussed. The data needed for construction and operation of a single or a series of lagoons are given.

Howells and Dubois (44) have compiled construction data of 31 oxidation pond installations in the region extending from Iowa through North Dakota. The variety of climatic and soil conditions, the size of contributing populations, varying from 600 to 12,300 persons, and the manner in which these will affect construction, operation, and maintenance, are all shown by tabulations and graphs. A concise view of the status of oxidation ponds and lagoons over the nation was obtained from state sanitary engineers (5). The compilation and accompanying discussion cover the requirements as to size, preliminary treatment, loadings, and effluent chlorination. Special comments by various state authorities are included.

A report (142) from Wisconsin discusses a four-unit system receiving settled sewage and trickling filter effluent from April 1957 to August 1958. The BOD loading varied from 2.2 to 23 lb/day/acre. The efficiency was comparable to secondary treatment, and during optimum climatic conditions, even superior BOD removal ranged from 65 per cent during late winter to about 90 per cent in summer. However, the trickling filter effluent was not appreciably reduced in BOD. Reduction in coliform organisms was greater than 98 per cent in 87 per cent of the samples, but less during the winter than during summer, when it usually was 99 per cent or more. This appraisal of oxidation pond performance is continued by Steinfeldt and Garrett (130). They answer the question: Considering the climatic and soil factors, including the greater area needed by an oxidation pond system, the possible performance and cost of operation, the dependence on climate, and balancing these factors against the known costs and possibilities of the standard treatment processes, which should a municipality adopt? Answers are suggested for the practical and theoretical questions to be considered by a municipality as to whether or not to adopt the oxidation pond process.

Webber (140) similarly gives the information a municipality should have to decide on the merits of a lagoon system. He gives the fundamental principles of construction, operation,

and maintenance, based on a BOD loading of 20 lb/day/acre. His statement that the sludge buildup is practically nil is probably based on this conservative loading.

Crist (29) reported on two years' operation of a lagoon system at Booneville, Arkansas. There are four ponds, operating as a two-parallel system, giving 22 days detention at a flow of 390,000 gpd. The BOD loading is 50 lb/day/acre. This system is distinctive in that pumps for recirculation as well as a chlorination system for the lagoon effluent are provided; neither of these has as yet been needed.

Russell (111) describes a unique installation of oxidation lagoons in which a special well with an automatic prefabricated pump installation will maintain the water depth at the designed four feet. The system consists of three lagoons having a combined area of 100 acres, arranged so they may be operated either in series or in parallel.

The largest lagoon system of this country is claimed by Everett, Washington (10). The primary lagoon is 136 acres in area, and the secondary 27 acres, each of them 4-ft deep. There will be a laboratory building for control of operations. The total cost, including 4,900 ft of sewer pipes, ranging from 24 to 48 in. in diameter, will be $293,095.

A novel lagoon installation in Eastern Europe is reported by Petryzkowski and Godwod (97). This system has four ponds, the first designed for organic fermentation in the acid stage; the second pond, where Ca is added, acts as a coagulation and settling basin; proteins ferment in the third pond; and the fourth pond is a cooling basin. The first three ponds reduce the organic load by 99.8 per cent.

Parker *et al.* (95) have described the performance of three systems of lagoons at Melbourne, Australia. These have been installed 6, 10, and 16 years ago, respectively, and the report is based on close study of each system during those years. Their ability to complete the treatment given by trickling filters, or to give complete treatment to normal or to storm-flow sewage, is shown by tabulated chemical analyses and graphs. The effectiveness of summer treatment as compared to winter, the formation of sludge deposits in each of the successive lagoons of a system, in anaerobic as compared to aerobic lagoons, and the appearance of odor or floating sludge, are noted.

Sewage Reuse

It is encouraging to note that the interest in the reuse of wastewater is increasing. A report (4) states that the County Board of Supervisors of Long Beach, California, has been publicly petitioned to sponsor legislation permitting the county to reclaim for reuse water that is now entering the ocean. The construction of a pilot plant to study such reclamation has been requested.

That reclaimed wastewater can be properly used for golf course irrigation is shown in Merz' (79) report of such use at numerous military and municipal golf courses for three years. The report also shows that such irrigation is especially valuable due to the fertilizing constituents of the reclaimed wastewater. Difficulties that may arise in certain soils due to the increased sodium content of the water are mentioned. Spray application of the water may spread *B. coli* through wind action, but chlorination will prevent this as well as possible odor nuisance.

According to the report of Scott (119), Bakersfield, California, uses its sewage plant effluent to irrigate a 2,500-acre farm. Part of the sewage is treated by primary settling only, the remainder receives additional aeration. Analyses showing treatment plant performance are given. Cotton and feed only are grown on the farms.

Another report on agricultural use of sewage, apparently untreated, comes

from the town of Zory in eastern Europe. According to Prochal (103) the N content of this sewage is 154 mg/l; P, 18 mg/l; and K, 52 mg/l. There is only a small amount of toxic sulfides, but a large amount of toxic lipids. If used as fertilizer this sewage should increase meadow crops 5 times, field crops should be doubled, and the yield of fish from ponds should be increased four-fold.

Industrial reuse of wastewater is receiving deserved attention. Scherer (112) gives the history of the agreement according to which Amarillo is furnishing sewage plant effluent meeting certain specifications, to the refinery located there. The refinery made certain contributions to the building of the new treatment plant, in addition to paying a specified amount to the City, based on the volume furnished the refinery. Emphasis is placed on the advanced design and instrumentation of the plant, needed for the complete control of the treatment process so as to be able at all times to meet the specifications of the effluent to be delivered. To be noted especially is the Texas Company's decision to reuse wastewater so as to preserve the groundwater for the future use of a progressive community.

The same situation is again discussed by Scherer and Alexander (113) from both the municipality's and industry's viewpoint. In this report is tabulated the analysis of the effluent in comparison to the refinery's specifications in the contract. This shows that a well-managed activated sludge plant can consistently produce water meeting the specified requirements. One serious plant upset, due to given wastes is noted. This led to remedial ordinances which are saving the treatment plant substantial funds. Included is a tabulation of the cost of the various steps of the treatment, together with the decrease of the volume cost as the volume treated increases. There also is described the treatment used at the refinery for preparing the effluent for use as boiler makeup and cooling water. It is interesting that an ammonia content as high as 15 mg/l has caused no corrosion.

Gloyna *et al.* (37) have investigated the possible reuse of wastewater throughout the most densely populated part of Texas, approximately the eastern third of the state, including 70 per cent of the population. The authors have studied these factors: (*a*) operations determining wastewater volumes, (*b*) the criteria of their quality, (*c*) reasons for and cost of preparing for reuse, (*d*) effects of public opinion on such reuse, and (*e*) administration of the reuse program, including any legal problems that might arise from any such reuse. The numerous climatic, hydrologic, industrial, and municipal factors needed for the study have been collected; numerous calculations have been made; and the results are presented in tabulations and graphs.

Ongerth and Harmon (92) consider reuse of wastewater strictly from the standpoint of sanitation. Their study includes groundwater recharge, both by direct and indirect injection; industrial reuse; and secondary domestic reuse, a term applied to water from a river that has received sewage plant effluent upstream. The possibility of underground travel of pathogens carried by wastewater is discussed. Of these, viruses are the greater travelers through the soil. The difficulties of carrying reclaimed wastewater in separate piping systems for domestic or industrial use and the legal liability for damage by pathogens carried by rivers that have received sewage plant effluent are discussed. The authors stress the fact that increasing population and growing industrialization demand a more exhaustive use of all water.

Metzler (81) gives examples of what Ongerth and Harmon call "secondary domestic reuse" of wastewater. He

gives additional information not previously published. The conclusion is that technically reuse is possible; industrially it has been done; but the aesthetic barrier is still to be surmounted.

The effects of a severe drought extending over a number of years, together with a rapidly increasing demand for water due to expanding industry and accompanying population growth on a water-poor Southwest, are the fundamental themes of a report by Connell and Berg (28). Examples of reuse of wastewater based on personal observations and answers to numerous questionnaires are given. Suggestions as to preparatory sewage treatment by the community and subsequent polishing of the effluent by the industrial users are given. There are numerous tabulations of reuse, analyses of wastewater as furnished by the community, and illustrations of apparatus and equipment for final treatment by users.

Schuette (117), believes that industry and the public agencies must come to agreement in their approach to water resources. He also states that the public agencies also have a serious obligation to provide objective, cooperative leadership. He points out that there are limitations to wastewater treatment. Some areas show that water resources are insufficient to meet the needs even if all wastewater is given complete treatment. He also discusses the problem of organic matter brought into bodies of water by storm runoff.

Miscellaneous

The fate of nickel and zinc during the treatment of sewage was studied by Stones (131)(132). It was found that sedimentation reduced the nickel concentration of sewage by about 20 per cent and the zinc content by 40 per cent. Biological filtration removed 40 per cent of the nickel and 30 per cent of the zinc in the filter influent. Activated sludge removed 30 per cent of the nickel and 60 per cent of the zinc in the settled sewage.

The National Institute for Water Research of South Africa (56) has been engaged in extensive research concerning the conservation of water supplies and the reclamation of industrial and sewage effluents. A part of this program included a comparative study of the efficiency in reduction of bacterial numbers by existing conventional sewage treatment plants. The numerical decreases in bacterial populations after primary sedimentation, biological filtration, activated sludge process, secondary sedimentation, and final sand filtration were compared with the reduction attained by the treatment of sand filter effluent, humus tank effluent, and primary biological filter effluent in units for further biological purification.

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ERRATA SHEET FOR TREATMENT PLANT DESIGN MANUAL

Corrections for the recently published FSIWA Manual of Practice No. 8 (ASCE Manual of Engineering Practice No. 36), "Sewage Treatment Plant Design," were published in the JOURNAL (**31**, 7, 818; July 1959; and **32**, 2, 146; Feb. 1960). These corrections have been placed on an errata sheet and are being inserted in all manuals sold in the future. Anyone desiring a copy of the sheet may obtain it by forwarding a request to the Federation office.

Sewage Works

USE OF FINAL SETTLING TANKS WITH STANDARD-RATE TRICKLING FILTERS

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Since 1939, the Public Health Service in cooperation with state water pollution control agencies and health departments has conducted an inventory of facilities for the disposal of sewage. Basic documents have been published at irregular intervals, the latest being the "1957 Inventory of Municipal and Industrial Waste Facilities" (1).

As part of the Inventory activity, statistical summaries of sewage works practice are prepared. Recent ones include a general summary of sewage works practice (2), and a report on sewage chlorination facilities (3).

This paper on the use of final sedimentation with standard-rate trickling filters closely parallels a similar study prepared from the "1948 Inventory" (4).

Data

This study is based on the 1957 edition of the Inventory and presents tabular data on the use of final sedimentation tanks with standard-rate trickling filters. Basic data are arranged by states, population groups based on community size, and major drainage basins in Tables I, II, and III, respectively. A map showing the basins is included in one of the earlier studies (3). In each of these tables, data are reported for the numbers of plants and the estimated population served for two categories of trickling filter plants—with and without final settling tanks. Comparative percentage data are included for both 1948 and 1957 in the state and population group tables. Such data are not available for 1948 by drainage basins.

In certain cases, filters are followed by some other secondary process rather than by a final sedimentation tank. The 1948 report listed these as footnotes, and the same procedure has been followed here. This practice is more extensive in 1957 than in 1948, and is commented on below.

Table IV presents experience through June 30, 1959, on applications for financial assistance from the Public Health Service in construction of trickling filter plants, under terms of Section 6 of P. L. 84-660. While the design requirements for a plant are determined in each instance by the various state regulatory agencies, this tabulation probably represents a fair composite of current practice in the construction of this type of plant.

The "1957 Inventory" contained data for the first time on the population equivalents, in terms of 5-day BOD, of the raw and treated wastes originating in community sewer sys-

tems. For those cases where matched data—population equivalent (P.E.) of both raw and treated wastes—were available, the percentage remaining was computed. The per cent remaining in the effluent was used, rather than per cent reduction in the plant, because of machine processing complications. These data have been summarized for standard-rate trickling filter plants with and without final settling tanks, and are presented in Tables V and VI. The frequency distributions are graphically presented in Figures 1 and 2.

Matched data were available for 1,295 of the 1,870 standard-rate trickling filter plants. The percentages remaining were listed sequentially by states and were examined for any gross bias that may have been introduced in the data reporting, such as equal reductions for all plants in a state. As a consequence, the data for 151 plants were removed. For the final statistical analysis, data were available for 58.4 per cent of the plants with final tanks, and 69.4 per cent of those trickling filter plants having no final sedimentation.

TABLE I.—Number of Trickling Filter Plants with and without Final Settling Tanks and Estimated Population Served by States

States*	Standard-Rate Trickling Filter Plants Having				Per Cent of Plants Without Final Settling in		Per Cent of Population Served Without Final Settling in	
	Final Settling Tanks		No Final Settling Tanks					
	Number of Plants	Estimated Population Served	Number of Plants	Estimated Population Served	1948	1957	1948	1957
Alabama	8	18,775	8	23,915	40.0	50.0	30.0	56.0
Arizona	3	38,000	2	2,500	66.7	40.0	29.8	6.2
Arkansas	4	39,500	3	2,550	60.0	42.9	24.3	6.1
California	33	275,560	23†	72,677	56.3	41.1	24.8	20.9
Colorado	1	1,230	12	46,565	88.9	92.3	95.5	97.4
Connecticut	2	3,800	2	9,400	0	50.0	50.0	71.2
Delaware	1	1,750	—	—	0	0	0	0
Florida	2	15,500	—	—	0	0	0	0
Georgia	32	335,400	17	33,600	50.0	34.7	18.4	9.1
Idaho	4	25,500	—	—	33.3	0	6.3	0
Illinois	154	533,611	6†	32,930	6.3	3.8	3.9	5.8
Indiana	32	161,170	5	10,550	13.6	13.5	5.2	6.1
Iowa	143	650,608	47	76,170	34.8	24.7	14.6	10.5
Kansas	154	388,315	11†	26,590	8.2	6.7	2.7	6.4
Kentucky	29	171,595	6	14,270	21.2	17.1	6.1	7.7
Louisiana	20	82,895	16	44,167	70.8	44.4	65.0	34.8
Maryland	10	28,887	—	—	9.1	0	0.1	0
Massachusetts	9	80,700	2	2,650	0	18.2	0	3.2
Michigan	8	257,393	10	43,980	42.9	55.6	3.4	14.6
Minnesota	73	159,574	3	1,480	1.3	3.9	0.5	0.9

* No trickling filter plants were reported for the District of Columbia, Maine, or Vermont.

† Certain of the trickling filter plants without final settling tanks are followed by oxidation ponds or application to land. An accounting of these is as follows: California, 15 plants serving a population of 58,255; Illinois, 1 plant serving 7,140; Kansas, 3 plants serving 11,240; Nebraska, 3 plants serving 2,200; Nevada, 2 plants serving 1,250; New Mexico, 2 plants serving 300; Oklahoma, 5 plants serving 11,850; Oregon, 1 plant serving 1,000; and Texas, 12 plants serving 41,470.

TABLE I.—*Continued*

States*	Standard-Rate Trickling Filter Plants Having				Per Cent of Plants Without Final Settling in		Per Cent of Population Served Without Final Settling in	
	Final Settling Tanks		No Final Settling Tanks					
	Number of Plants	Estimated Population Served	Number of Plants	Estimated Population Served	1948	1957	1948	1957
Mississippi	1	12,000	5	21,000	85.7	83.3	65.6	63.6
Missouri	108	293,100	16	21,204	34.2	12.9	20.6	6.7
Montana	—	—	1	3,000	—	100.0	—	100.0
Nebraska	24	37,484	33†	130,042	60.5	57.9	84.0	77.6
Nevada	—	—	2†	1,250	—	100.0	—	100.0
New Hampshire	3	2,270	—	—	0	0	0	0
New Jersey	39	331,110	12	91,943	11.5	23.5	6.5	21.7
New Mexico	6	47,700	10†	16,150	75.0	62.5	67.1	25.3
New York	38	184,080	9	169,100	15.4	19.1	36.0	47.9
North Carolina	25	323,885	15	58,230	56.3	37.5	24.8	15.2
North Dakota	3	22,800	8	56,800	88.9	72.7	78.8	71.4
Ohio	61	569,560	6	12,960	17.6	9.0	15.9	2.2
Oklahoma	69	277,932	70†	157,210	88.3	50.4	76.8	36.1
Oregon	19	65,300	2†	1,100	7.7	9.5	17.2	1.7
Pennsylvania	53	535,510	10	37,520	15.9	15.9	19.0	6.5
Rhode Island	2	19,450	—	—	0	0	0	0
South Carolina	16	114,900	8	11,350	65.0	33.3	54.5	9.0
South Dakota	35	116,155	5	4,595	32.3	12.5	17.0	3.8
Tennessee	14	106,105	7	221,135	50.0	33.3	35.3	67.6
Texas	51	981,410	48†	171,280	76.4	48.5	30.3	14.9
Utah	6	61,790	1	400	—	14.3	—	0.6
Virginia	16	33,960	13	24,540	32.4	44.8	22.0	41.9
Washington	4	30,360	—	—	0	0	0	0
West Virginia	4	20,100	1	18,500	20.0	20.0	47.9	47.9
Wisconsin	90	168,000	2	1,735	4.5	2.2	1.9	1.0
Wyoming	3	50,300	1	1,000	100.0	25.0	100.0	1.9
Total	1,412	7,675,024	458	1,676,038	34.3	24.5	20.1	17.9

Discussion

Standard-rate trickling filter plants comprise over 40 per cent of all secondary treatment plants, and serve 21.6 per cent of the population connected to secondary plants. The importance of this method of biological treatment is evident both from the standpoint of numbers currently in use and those presently being constructed as shown in Table IV.

In 1948, more than a third of trickling filter plants did not have final settling tanks, while in 1957 about 1 in 4 did not have final tanks (Table VII). Between these same periods there were actual decreases in the number and the population served by plants without final tanks. The use of oxidation ponds following trickling filters increased substantially.

In 1957, trickling filter plants without final sedimentation served about 4 per cent of the population served by secondary treatment and comprised almost 10 per cent of the total secondary treatment plants.

TABLE II.—Number of Trickling Filter Plants with and without Final Settling Tanks and Estimated Population Served by Population Size Groups

Population Size Groups	Standard-Rate Trickling Filter Plants Having				Per Cent of Plants Without Final Settling in		Per Cent of Population Served Without Final Settling in	
	Final Settling Tanks		No Final Settling Tanks					
	Number of Plants	Estimated Population Served	Number of Plants	Estimated Population Served	1948	1957	1948	1957
Under 500	86	28,547	45	17,510	38.3	34.4	52.9	38.0
500–1,000	229	157,336	88	55,156	36.7	27.8	36.1	26.0
1,000–5,000	682	1,462,741	231	430,637	37.9	25.3	34.6	22.7
5,000–10,000	224	1,361,505	47	235,060	26.2	17.3	27.1	14.7
10,000–25,000	130	1,477,027	35	383,125	26.0	21.2	23.1	20.6
25,000–50,000	27	650,195	4	78,200	17.6	12.9	16.1	10.7
50,000–100,000	15	982,260	3	200,600	26.7	16.7	25.4	17.0
Over 100,000	19	1,555,413	5	275,750	22.7	20.8	7.1	15.1
Total	1,412	7,675,024	458	1,676,038	34.3	24.5	20.1	17.9

As in 1948, Oklahoma and Texas reported the largest number of trickling filter plants without final sedimentation, 70 and 48, respectively. Tennessee and Texas reported the largest populations served by such plants. In 11 states, the number of plants without final settling tanks exceeds or equals

TABLE III.—Number of Trickling Filter Plants with and without Final Settling Tanks and Estimated Population Served by Major Drainage Basins

Major Drainage Basins	Standard-Rate Trickling Filter Plants Having				Per Cent of Plants Without Final Settling in 1957	Per Cent of Population Served Without Final Settling in 1957
	Final Settling Tanks		No Final Settling Tanks			
	Number of Plants	Estimated Population Served	Number of Plants	Estimated Population Served		
Northeast	46	263,515	11	179,150	19.3	40.5
North Atlantic	110	872,542	27	131,833	19.7	13.1
Southeast	85	817,260	52	131,895	38.0	13.9
Tennessee River	10	60,900	8	217,235	44.4	78.1
Ohio River	142	1,015,560	23	79,640	13.9	7.3
Lake Erie	19	82,485	1	910	5.0	1.1
Upper Mississippi	405	1,366,801	44	142,490	9.8	9.4
Western Great Lakes	42	356,323	13	45 895	23.6	11.4
Missouri River	214	566,559	87	227,641	28.9	28.7
Southwest-Lower Miss.	219	866,559	119	291,102	35.2	25.1
Colorado River	6	50,390	3	2,900	33.3	5.4
Western Gulf	50	899,010	43	150,320	46.2	14.3
Pacific Northwest	26	118,360	2	1,100	7.1	0.9
California	33	277,460	20	57,980	37.7	17.3
Great Basin	5	61,300	5	15,947	50.0	20.6
Total	1,412	7,675,024	458	1,676,038	24.5	17.9

TABLE IV.—Trickling Filter Plants Approved for Construction Under PL-660 as of June 30, 1959

State	With Final Settling	Without Final Settling
Alabama	4	—
Arkansas	2	—
California	2	2
Colorado	3	—
Connecticut	1	—
Florida	3	—
Georgia	6	—
Illinois	7	—
Indiana	5	—
Iowa	21	—
Kansas	16	2
Michigan	5	1
Minnesota	4	—
Missouri	8	—
Nebraska	4	—
New Mexico	5	—
North Carolina	5	—
Ohio	8	—
Oklahoma	6	2
Oregon	5	—
Pennsylvania	5	—
Rhode Island	1	—
South Carolina	1	1
Tennessee	2	—
Texas	5	—
Utah	5	—
Virginia	5	—
Washington	1	—
Wisconsin	7	—
Total	152	8

those having such tanks. However, in only nine states does population served by plants without final settling tanks exceed that served by plants with final tanks.

On the basis of population groups, the percentage of trickling filter plants without final tanks is largest in communities of less than 5,000 population. Approximately 37 per cent of the trickling filter plants in these groups do not have them, and these comprise almost 11 per cent of the total secondary plants serving communities of less than 5,000 population.

The Southwest-Lower Mississippi basin has the largest number of plants having no final sedimentation as well as the largest population served by such plants. Plants of this type are least common in the Lake Erie and Pacific Northwest basins.

The data shown in Tables V and VI were examined in terms of 5 per cent intervals of percentage of the population equivalent remaining after treatment. The frequency distributions prepared on this basis gave a skewed curve which did not present a good fit of a normal frequency distribution curve.

Since the distributions were significantly skewed to the right, the data were then examined in terms of the logarithms of the per cent population equivalent remaining. The distribution of these logarithms was found to be not significantly different from a normal curve when tested for skewness. The means of these distributions show that trickling filters followed by final sedimentation removed 81.5 per cent of the population equivalent entering the treatment plant and that those plants having no final tanks removed only 71.0 per cent. Since these per cent removals are geometric means, they are less affected by extreme values and indicate somewhat more removal than the arithmetic means of 78.8 and 66.1 per cent for trickling filters with and without sedimentation, respectively.

Figures 1 and 2 show the normal curves derived from the distribution of logarithms for both types of trickling filters. Figure 3 shows the same normal curves plotted on probability paper which enables one to read directly the percentage of the distribution having "X per cent of BOD remaining." It also enables a direct comparison of the two types of filters.

The examination of the median values of Table V for those trickling filter plants with final sedimentation shows no definite increase in percentage removals as the size of communities increases. However, such a trend is

TABLE V.—Reported Frequency Distribution of Efficiencies of Trickling Filter Plants with Final Settling Tanks (Per Cent Population Equivalent Remaining Discharged to Streams)

Per Cent Pop. Equiv. Remaining Mid-Point	Total	Population Size Group (Thousands)							
		Under 0.5	0.5–1	1–5	5–10	10–25	25–50	Over 50–100	100
Under 5	10	1	2	5	2	—	—	—	—
5	29	1	3	13	7	4	—	1	—
10	155	5	20	78	28	15	4	3	2
15	197	11	42	97	28	9	6	2	2
20	139	8	20	74	20	12	4	1	—
25	145	18	28	64	17	14	2	1	1
30	56	4	9	35	7	1	—	—	—
35	14	—	1	7	2	2	2	—	—
40	26	1	6	12	3	4	—	—	—
45	8	—	1	4	2	1	—	—	—
50	17	1	2	7	3	3	1	—	—
55	2	—	—	1	—	1	—	—	—
60	1	—	—	1	—	—	—	—	—
65	7	—	1	4	—	2	—	—	—
70	5	—	2	2	—	1	—	—	—
75	4	—	—	3	—	1	—	—	—
80	1	—	1	—	—	—	—	—	—
85	4	—	—	3	1	—	—	—	—
90	—	—	—	—	—	—	—	—	—
95	2	—	—	2	—	—	—	—	—
Over 95	4	—	1	2	1	—	—	—	—
Total	826	50	139	414	121	70	19	8	5
Median	19	20	20	19	15	20	17	—	—

TABLE VI.—Reported Frequency Distribution of Efficiencies of Trickling Filter Plants without Final Settling Tanks (Per Cent Population Equivalent Remaining Discharged to Streams)

Per Cent Pop. Equiv. Remaining Mid-Point	Total	Population Size Group (Thousands)							
		Under 0.5	0.5–1	1–5	5–10	10–25	25–50	50–100	Over 100
Under 5	10	3	2	2	3	—	—	—	—
5	6	2	—	2	1	1	—	—	—
10	19	2	2	6	5	4	—	—	—
15	20	1	4	10	3	1	1	—	—
20	28	2	4	12	6	2	—	1	1
25	56	4	12	27	5	5	1	1	1
30	58	9	15	25	5	4	—	—	—
35	14	1	5	6	1	1	—	—	—
40	26	4	5	15	—	1	1	—	—
45	11	2	4	5	—	—	—	—	—
50	23	3	5	10	3	2	—	—	—
55	4	1	2	1	—	—	—	—	—
60	9	1	2	5	—	—	—	—	1
65	7	—	—	7	—	—	—	—	—
70	10	1	1	8	—	—	—	—	—
75	1	—	1	—	—	—	—	—	—
80	2	—	1	1	—	—	—	—	—
85	6	—	1	5	—	—	—	—	—
90	2	—	—	2	—	—	—	—	—
95	—	—	—	—	—	—	—	—	—
Over 95	5	—	1	3	1	—	—	—	—
Total	317	36	67	152	33	21	3	2	3
Median	30	30	30	30	21	19	—	—	—

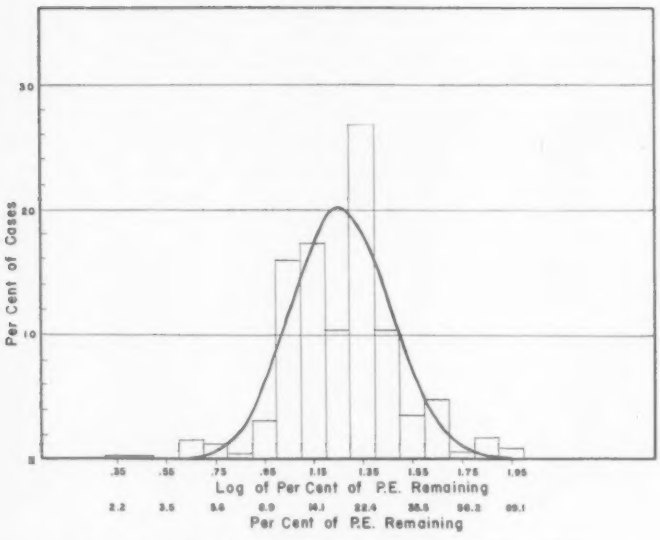
Per Cent of Cases
30
20
10
0
.35 .55 .75 .95 1.15 1.35 1.55 1.75 1.95
Log of Per Cent of P.E. Remaining
2.2 3.5 5.6 8.9 14.1 22.4 35.5 56.2 89.1
Per Cent of P.E. Remaining

FIGURE 1.—Efficiencies of trickling filters with final tanks.

apparent for those plants having no final settling tanks. For the smaller population groups, serving communities of under 5,000 population, the median percentage removal is about 70 per cent which increases to 81 per cent removal for plants serving communities of 10,000 to 25,000 population.

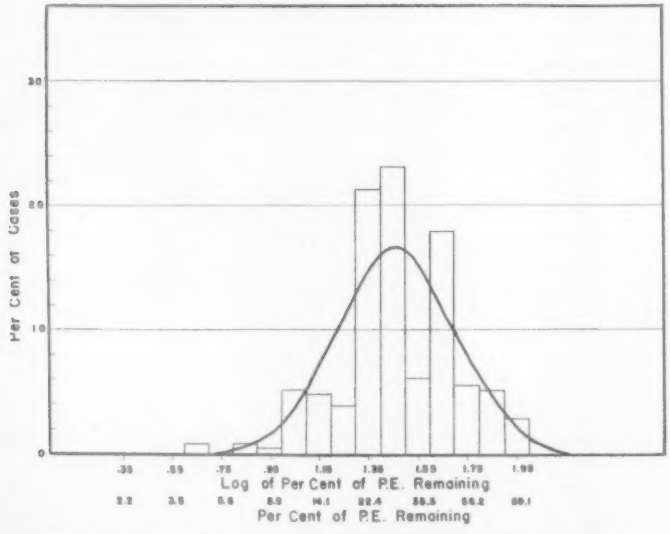

FIGURE 2.—Efficiencies of trickling filters without final tanks.

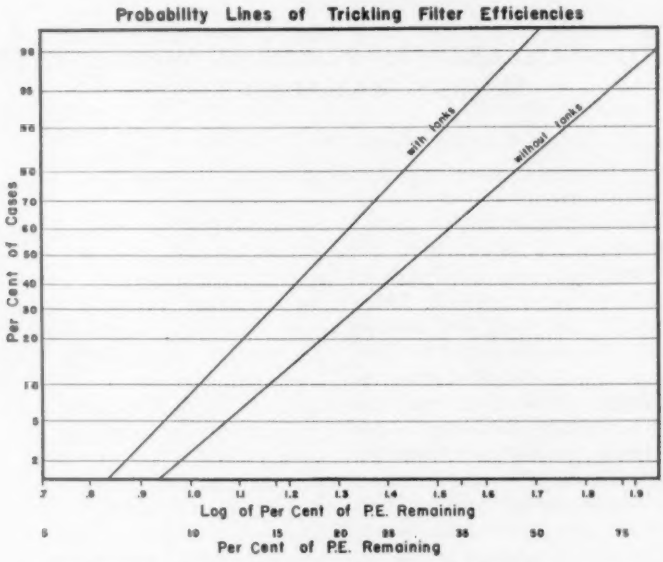
Probability Lines of Trickling Filter Efficiencies
with tanks
without tanks
Per Cent of Cases
Log of Per Cent of P.E. Remaining
Per Cent of P.E. Remaining

FIGURE 3.—Probability lines of trickling filter efficiencies.

TABLE VII.—Accounting of Final Tanks for Trickling Filter Plants

Year	With Final Tanks		Without Final Tanks	
	Number of Plants	Estimated Population Served	Number of Plants	Estimated Population Served
1948	997	7,249,650	520	1,827,470
1957	1,412	7,675,024	458	1,676,038

While any generalizations from these data are subject to many qualifications, it appears that the use of final sedimentation increases plant efficiency by 10 per cent when measured in terms of BOD.

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THIS YEAR THE FEDERATION MEETING IS EARLY

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INSURANCE AND ITS PLACE IN WASTEWATER WORKS MANAGEMENT *

By Ralph E. Roderick

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In placing between 30 and 40 sewage treatment plants in operation in the Pacific Northwest over the past 12 years, the problem of adequate insurance programs has been encountered repeatedly. How much and what kind of insurance should be carried on the plant facilities has been the repeated question. At first, it was recommended that the cities contact their local insurance associations for this information. In discussing the problem with the insurance agents, however, it was soon realized that proper advice regarding this phase of sewage works management required a knowledge of the physical components of treatment facilities and the insurance business.

Most insurance agents have no particular difficulty in developing the insurance rate which will be required for the insurance coverage desired. The major problem is to develop the amount of coverage the municipality should carry. In other words, what portion of the plant should be considered as subject to a potential loss of any magnitude resulting from fire, explosion, wind, flooding, or similar forms of physical violence? In addition to fire and extended coverage insurance, workmen's compensation, general liability, and automobile liability insurance probably should be included in the over-all insurance program for the treatment facilities.

Reports regarding violent explosions which have resulted from accidental ignition of a proper mixture of oxygen and sludge gases have been common. Certainly, such reports are properly in the mind of the designing engineer as he works out the many details connected with the sludge digestion process and more especially in connection with the collection and disposal of the sludge gas. On the other hand, if the designing engineer is not careful, it is easy to let such reports magnify the problem and influence his judgment to such an extent that expensive gasproof construction may be specified where it is actually not justified, based on loss experience records. This can also be the case with plant management personnel when they first place the new facilities into operation. It is possible that these reported explosions have influenced municipalities into obtaining insurance for units in the treatment plant which have no possibility of loss by fire or explosion. It is believed that full or nearly full coverage is often carried just because there is no reliable information available to the plant personnel to help them to establish in an intelligent manner which units should be covered. As a result, the old rule of "better be safe than sorry" is adopted, especially where public property is involved and where a loss would result in criticism of the administration, even though such losses might be so minor that they place no particular burden on the public treasury.

Insurance Terminology

In order to understand and to be able to discuss insurance problems, there are a few terms common to the insurance business which probably should be explained so they can be better understood by others.

* Presented at the 32nd Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Dallas, Tex.; Oct. 12–15, 1959.

The various cities throughout the country are all rated as to class. This rating is established by representatives of the National Board of Fire Underwriters. The class of fire protection is computed, based on the result of a survey to establish the ability of the community's fire-fighting facilities, as well as the capabilities of the water supply and distribution system. There possibly are a few major cities in each state which are rated as high as Class II. It is seldom, however, that any city will be rated as high as Class I. Most cities of a population of 50,000 or under will probably be rated as Class IV, V, or VI, with those having inferior fire-fighting facilities rated in the lower classes. Fire insurance rates are directly affected by the municipality fire protection rating.

Another item in the rate structure is known as the rating table number. This rating table number is established by the location of the particular improvement with respect to fire hydrants and other fire-fighting facilities.

Another important item in the insurance rate structure is known as class of risk. For an example, the community hospital may be and probably is classed as a Class A risk, while any frame construction most probably would be in the lowest class, which is a Class D. In general, the Class A and A-B risks are of masonry construction with masonry roofs and floors. Class B would be concrete wall construction with wood floors and roofs. The Class C would be concrete block construction with wood floors and roofs. Without a doubt, the Class D risk would demand the highest rate.

The Z factor adjusts insurance rates based on the use of the structure. For instance, a digester tank would have a Z factor of 0.21, while a control building might have a Z factor of 0.18. The difference is the possible explosion hazard created by gases produced in the digester. Other buildings which do not contain boilers or similar type equipment might have a Z factor lower than the 0.18 quoted for the control building.

Types of Insurance

Fire insurance carried on a residence is most commonly purchased for a specific value known as specific insurance. Commercial buildings are insured either for specific insurance or may be insured under a co-insurance or average-clause insurance. The specific insurance means just what the word implies. The owner of the property may desire to carry insurance in a specified amount on an improvement. In this instance, the insurance company will pay all losses resulting from a fire up to the specified amount of the insurance policy, with the owner absorbing any loss in excess of the specified amount. The cost of the specific insurance is based on a fixed amount per fixed value of insurance.

Because of the probability that most commercial buildings and similar structures would not sustain a complete loss in case of fire, the insurance companies offer a policy in which there is a reduced premium rate if 70 per cent to value or greater is carried. This type of insurance is known as average-clause insurance or, in some places, may be known as co-insurance. The advantage of this type of insurance is that, in most instances, the owner will find he can carry insurance in the amount of 70 per cent to value or greater on the entire replacement cost at about the same rate he would be paying for specific insurance of say 50 per cent or less of the value of the replacement cost. If a piece of property, therefore, is insured under the average clause of, say, 80 per cent to value, the insurance company guarantees to pay the replacement cost in case of loss up to 80 per cent of the value of the replacement cost. If, however, the specific insurance of, say, 50 per cent of the value is carried, then, in the event of a loss, the insurance company would pay only

up to the specified amount of insurance carried, or 50 per cent of the replacement cost. The main difference is, then, that the insurance company, without much increase in insurance rate, is willing to take the risk that the loss in case of fire would not approach the replacement cost.

Rates and Exemptions

Insurance rates are normally computed on an annual premium basis and then adjusted to a 3- or 5-yr premium by using a multiplying factor of approximately 2.7 for the 3-yr or 4.4 for the 5-yr premium. This amounts to about a 10 per cent reduction per year for the 3-yr policy and about 13 per cent reduction for the 5-yr policy.

In computing the replacement value of a piece of property to be covered by average-clause insurance or co-insurance, whichever it may be called, the insurance company allows the insured to deduct the value of the following items, since they will be covered either by other types of insurance or there is no possibility of damage requiring replacement: (*a*) building content; (*b*) engineering and architectural fee, except that of supervision of reconstruction; (*c*) boiler and foundations, including gratings; (*d*) chimneys and stacks, areaway retaining walls, headwalls, and similar construction when not forming part of any building; (*e*) costs for excavation, grading, filling, dredging, or clearing of site; (*f*) land values; (*g*) railroad tracks, roadways, walls, dikes, or similar items not forming a part of any building; (*h*) floors of noncombustible material when laid on the ground; (*i*) foundations of buildings, machinery, or equipment which are below the surface of the lowest floors; (*j*) piling under the buildings and structures; and (*k*) piping, drains, tanks, wiring, or similar equipment when described as underground.

To cover replacement costs resulting from physical violence of various natures, it is usually recommended that the owner carry fire and extended coverage insurance on the building and its contents, as well as boiler insurance on the heating facilities. Probably, none of these types of insurance needs explanation except the extended coverage insurance.

Extended Coverage

The term "extended coverage insurance" is often interpreted to cover any loss resulting from any cause. This is not the case. In most policies containing the extended endorsement, the coverage is specifically noted to cover losses from windstorm, hail, explosion, riot, civil commotion, aircraft, vehicle, and smoke. It would not, unless specifically stated, cover any loss resulting from water in the form of flood, water backing up through sewers or drains, ground water exerting external pressures on floors, etc.; nor would it cover losses resulting from nuclear reaction or radiation; neither would it cover any other form of peril not specifically listed as covered.

Questionnaire Study

In order to develop some definite information regarding the present practice of plant insurance, a short questionnaire was sent to over 500 superintendents of sewage treatment plants in 48 of the 50 states.

Plant Coverage

The first portion of the questionnaire developed the estimated value of the plant facilities, together with the population served by the plant, plus a section covering the value of fire and extended coverage insurance carried on the plant. It was surprising to find that about 10 per cent of the plants reporting stated that they carried no insurance at all. It was also interesting to note that only three of this group thought they should be carrying insurance. Of course, there were a few representing large metropolitan areas

which are self-insured. It was also interesting to note that there were several which reported their insurance coverage was equal to the estimated replacement cost of their entire treatment plant facilities.

The replacement value of the plants reported varied from a minimum of about $60,000 to nearly $60,000,000. About 25 per cent of those reporting stated they carried fire and extended coverage insurance of 90 per cent of the plant value or over. The rest of the group varied from 5 per cent of plant value to 90 per cent, with about 60 per cent reporting insurance coverage equal to 50 per cent of the replacement costs or greater.

Determination of Amount

A second portion of the questionnaire had particular reference to the methods used in establishing the amount of insurance carried. About 50 per cent of those reporting indicated that the amount of insurance carried was established following a conference of insurance personnel with the plant management or consulting engineers. Of the remaining 50 per cent, approximately three out of four indicated that the amount of insurance carried was established solely by those in the insurance business. Some 20 per cent of the time, it was established by the consulting engineers, and only about 5 per cent of the plants had the amount of coverage established by the plant management personnel alone. This seems to point out that the amount of coverage carried is, therefore, to a large extent established by those in the insurance business. This may be a healthy situation and again may be just good salesmanship.

Losses

The third section of the questionnaire was used to try to establish losses as experienced in the several plants contacted. Of the approximately 130 plants reporting, the total value of claims paid amounted to $72,276. This amount was paid on some 39 claims, an average of approximately $1,850 per claim. Of the 39 claims reported, the maximum amount of any claim paid was $15,858, with 24 of the 39 claims amounting to less than $1,000 each. The claim for $15,858 resulted from loss by fire caused by a broken oil line in the preheater of a flash dryer. This same plant reported a claim for $9,500 which had resulted from an explosion or rupture in the fixed cover on the primary digester. Another plant reported a loss of $10,000 resulting from the collapse of a fixed digester cover.

Some of the plant superintendents reported interesting losses. One reported a loss resulting from a fire in the main pumping station at the treatment plant. This fire resulted from an unattended drop cord which had been left in a wet well of the raw sewage pumping station with the light burning. With the influent exceeding the volume being pumped, the raw sewage in the wet well rose to such an elevation that the light bulb was contacted and shattered, the resultant spark evidently igniting the explosive mixture of sewage gases and oxygen present in the wet well. This resulted in a loss of approximately $5,000. The same plant reported that, from time to time, workmen at a meat packing plant which uses a naphtha recovery system for grease recovery would dump a good many gallons of naphtha and grease directly into the sewer system. Whenever the plant personnel detected the presence of the naphtha in the raw sewage in the covered primary clarifier building, they would immediately disconnect all electrical facilities and evacuate the building. There existed, however, a large untrapped sewer leading from the primary clarifier building to the raw sludge pump house. The naphtha fumes from the primary clarifier evidently entered the untrapped sewer and traveled to the pump house where they were ignited by a spark,

probably from the hot water heater. The loss from this explosion amounted to about $8,000.

Several of the claims for losses resulted from hail storms damaging the glass-covered sludge beds. In general, the fire losses reported were minor in size and usually resulted in damage to the boiler equipment.

Adequacy of Insurance

The questionnaire also asked the plant superintendents' opinions relative to the adequacy of the insurance being carried. Approximately 20 per cent of those reporting felt that the insurance, as now carried, was too low; about 8 per cent thought it was too high; and the remaining 72 per cent considered it to be about right.

Other Questions

The National Board of Fire Underwriters was contacted in an attempt to obtain information relative to losses experienced by waste treatment facilities. It was surprising to learn that the Board does not receive reports of losses under $20,000 in value. It was also surprising to learn that they have a record of only one property loss and that was in an amount of about $45,000.

The questionnaires returned from the various plant superintendents indicated that, in nearly all states, workmen's compensation insurance is required and that, in many of the states, this insurance is provided by the state workmen's compensation commission. This phase of the plant insurance is, therefore, quite well defined and of no particular problem to the plant administration personnel.

Review of Program

General liability and automobile liability insurance for employees at the sewage treatment plant is similar in most respects to that of other municipal functions so that standard insurance usually is quite adequate.

Engineers with the insurance companies are always glad to review proposed plans for sewage treatment facilities and to suggest changes which possibly could be made to reduce materially the insurance rates. This phase of the design may be overlooked too often by the consulting field. There should at least be a check list of the various conditions insurance companies consider in establishing the insurance rates. It also would be well if the plant superintendent would review the insurance rate with his insurance agent to see if there are hazards in the plant area which might be eliminated at no great cost in order to obtain the lowest possible rate. For instance, one plant had its base rate increased by 10 points because the propane gas tank did not have a tamperproof lid and was located within 30 ft of the control building. By relocating the tank and adding a hasp and padlock, this added cost was eliminated.

A primary treatment plant serving a population of about 50,000 had a construction cost of approximately $750,000 in 1954. Fire insurance has been obtained under a 90-per cent average clause, with the replacement cost established as $746,082. When, however, the allowable exclusions were deducted, payment should have been on a replacement value of $367,150. The insurance people in this case had failed to advise the city of the allowable exclusions and the rate had been nearly twice what it should have been.

With these conditions in mind, it is believed that there is need for a better understanding of the insurance program. A recommendation is now made that there should be formed a special committee composed of plant superintendents, engineers, and representatives of the insurance business. This committee should investigate the record of losses experienced by sewage treatment plants and develop recommendations which could be used as guides in establishing an intelligent insurance program.

Industrial Wastes

LABORATORY STUDIES OF REMOVAL AND SEGREGATION OF FISSION PRODUCTS FROM REACTOR WASTES

By Herman L. Krieger, Abraham S. Goldin and Conrad P. Straub

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Rapid development of reactor technology has brought about an increase in the number and size of proposed and completed reactor stations, and a corresponding increase in problems connected with a nuclear power economy. Although nuclear power is not at present economical in the United States, it is already in use in other countries and in special applications where conventional energy sources are less satisfactory. Because of the large volume of waste from all nuclear operations, reduction in the cost of waste treatment and disposal could contribute substantially to the development of competitive nuclear power, and influence its future economical growth (1) (2) (3).

At present, fuel elements must be removed from a reactor before all the fissionable material is consumed. The fuel element is processed chemically to recover the fissionable material for refabrication and reuse (4) (5) (6). This fuel reprocessing produces a liquid waste which has a high acid concentration, a high inert salt content, and a significant radiation hazard potential. These wastes are presently stored in tanks at great expense, and there is some question of tank integrity as to their long-term corrosion and radiation resistance.

A previous publication (7) contains references to studies of proposals for solidifying the waste. Alternative proposals (2) (3) (8) and subsequent investigations (9) (10) (11) (12) (13) (14) have presented other treatment ideas. All agree that some method other than direct storage is desirable.

This report is an extension of earlier studies (7) (15) which proposed separation of the more critical radionuclides to permit short-term storage of the bulk of the waste. These studies were performed on a synthetic acid aluminum nitrate waste whose calculated composition was representative of a fission product waste resulting from the chemical processing of an aluminum clad fuel element. By concentrating the hazardous long-lived fission product components of the waste, smaller and less costly storage tanks can be used and the residual waste is more suitable for disposal into the environment.

The effectiveness of cesium coerystallization and strontium coprecipitation as specific treatment methods for respective nuclide recovery has been reported (16) (17). In coerystallization, removal of activity is based on the low solubility of cesium alum in the presence of a high concentration of the lighter alkali alums. The basic concept of crystallization proposes that slow cooling, moderate stirring, and low temperatures favor crystal formation (18). These parameters were studied

initially. Slow stirring at low temperatures was found most effective in achieving complete crystallization.

Of great analytical importance is the coprecipitation phenomena, which refers to the occlusion of one cation by incorporation of foreign ions during formation of precipitate. For totally effective coprecipitation the foreign ion must fit into the crystal lattice of the precipitate. It then becomes occluded in the form of mixed crystals or is adsorbed during the growth of the primary particles to larger dimensions (19) (20) (21) (22).

Barium sulfate, the least soluble of the sulfates, carries down the alkaline earth salts and aluminum as it is precipitated (23). Although Al^{+++} inhibits complete precipitation of $BaSO_4$, it was expected that preliminary removal of Al^{+++} in the potassium alum, combined with excess sulfate ion, would permit adequate precipitation.

Reagents

All chemicals used were of analytical reagent grade, where available, otherwise of C. P. grade. The list included: (*a*) potassium sulfate powder —K_2SO_4; (*b*) anhydrous sodium sulfate—Na_2SO_4; (*c*) barium nitrate solution—$Ba(NO_3)_6$, in which 15 ml $\cong$ 1.0 g Ba^{++}; (*d*) cupferron—6-per cent aqueous solution (w/v); (*e*) tributyl phosphate—$(C_4H_9)_3PO_4$; and (*f*) No. 36 iron wire.

Tracers used are listed in Table I.

With the exception of the $Sr^{85, 89}$ tracer, which was purchased from the Atomic Energy of Canada, Limited, Ottawa, Ontario, all tracers were obtained from the Oak Ridge National Laboratory, Oak Ridge, Tennessee.

TABLE I.—List of Tracers and Their Chemical Forms

Tracers	Chemical Form
$Sr^{85,89}$	$SrCO_3$
Sr^{90}-Y^{90}	$SrCl_2$
Y^{91}	YCl_3
Cs^{137}-Ba^{137m}	CsCl
Ru^{106}-Rh^{106}	$RuCl_3$
Ce^{144}-Pr^{144}	$CeCl_3$
Zr^{95}-Nb^{95}	Oxalate complex

Measurements

In all studies, aliquots of the aqueous phase were taken before and after each treatment, and counted for β activity using a proportional counter converter (NMC Model PC-11) and a decade scaler (NMC Model DS-1). To minimize self-absorption losses, 0.1-ml aliquots were dried in a 2-in. aluminum planchet for counting. A larger sample would have left a large residue, because of the high $Al(NO_3)_3$ concentration, which would have increased the counting error appreciably. When a large concentration of tracer activity was used, it was necessary to make 1:10 dilutions of the initial aliquot.

For obtaining gamma spectra, a 100-channel (RIDL Model 3300) or a 20-channel (Baird-Atomic Model 520) analyzer was used, in conjunction with 2-in. sodium iodide (thallium-activated) scintillation detectors (Harshaw). Samples were placed in a 5-ml plastic vial and introduced into a well-type crystal or in a 150-ml beaker for counting on a solid crystal. Thus, the behavior of the specific gamma-emitting radionuclides in each treatment process could be followed. The predominant gamma energies of the nuclides in question are listed in Table II, and spectra of a typical acid $Al(NO_3)_3$ waste containing Ce^{144}, Ru^{106}-Rh^{106}, Cs^{137}-Ba^{137m}, and Zr^{95}-Nb^{95} at various stages of treatment are shown in Figure 1.

These spectra indicate that the Cs^{137} peak at 0.66 Mev was still very much in evidence during these particular treatment steps. Incomplete removal of specific gamma activities is spotlighted by these curves, so that subsequent treatment was directed specifically toward the radionuclide in question, thereby achieving more efficient utilization of the treatment processes.

TABLE II.—Fission Products in Acid $Al(NO_3)_3$

Tracer	Mode of Counting	Predominant Gamma Energy (Mev)	Carrier	Carrier Conc. (mg/l)
Cs^{137}-Ba^{137m}	Ba^{137m} γ at equilibrium	0.66	Cs	21.6
Sr^{89}	Sr^{89} β	—	Sr	9.4
Y^{91}	Y^{91} β	—	Y	4.4
Ce^{144}-Pr^{144}	Ce^{144} and Pr^{144} γ at equilibrium	0.13	Ce	23.6
Ru^{106}-Rh^{106}	Rh^{106} γ at equilibrium	0.52	Ru	11.2
Zr^{95}-Nb^{95}	Zr^{95} and Nb^{95} γ not at equilibrium	0.72 and 0.75	Zr	25.6
—	—	—	Ba, La, Nb, Pr, Mo	63.4
—	—	—	Tc*, Rh*, Pd*, Xe*, Kr*	40.8
Total	—		—	200.0

* Not added.

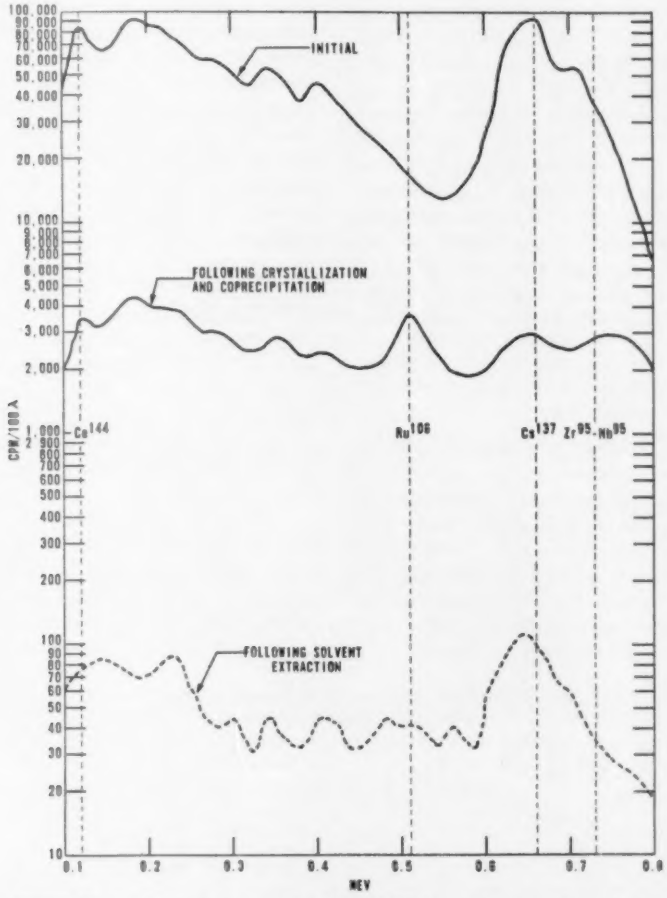

FIGURE 1.—Gamma scans of acid $Al(NO_3)_3$ waste at various stages of serial treatment.

TABLE III.—Preliminary Cocrystallization Results in Which Acid $Al(NO_3)_3$ is Stirred 60 min, Allowed to Stand 3 hr, and Filtered

Temp. (°C)	K_2SO_4 (g/100 ml)	Na_2SO_4 (g/100 ml)	Per Cent Removed					
			Cs^{137}	Sr^{89}	Ru^{106}	Ce^{144}	Y^{91}	Zr^{95}-Nb^{95}
20	6	10	84.3	—*	—	—	—	—
2	6	15	99.1	—	—	—	—	—
0	3	15	99.9	5	0	0	0	0
0	6	15	99.99	—	—	—	—	—

* No test made.

Preliminary Studies

A synthetic fission product solution, representative of a waste from the chemical processing of aluminum clad fuel elements, was prepared. It contained 1.6 M aluminum nitrate, 0.16 M nitric acid, 0.02 M sulfuric acid, and the nonradioactive carriers listed in Table II. Of the 200.0-mg/l stable carrier concentration present, all but 40.8 mg/l were added. These concentrations are based on calculations for a power reactor waste cooled 30 days after 30 days in the reactor. Each treatment method was evaluated after the addition of one or more tracer activities to 100-ml aliquots.

Cesium-Potassium Alum Cocrystallization

The effects of temperature, stirring time, and reagent concentration were evaluated for cesium-137 removal. Results of the crystallization study (Table III) show that, with proper temperature and dosage of potassium and sodium sulfate, the cesium activity can be removed specifically and effectively from the acid $Al(NO_3)_3$ solution.

To ensure complete crystallization, at least three hours' standing at zero degrees centigrade was essential. On several occasions of shorter standing times, crystals of cesium potassium alum later formed in the filtrate from the subsequent $BaSO_4$ precipitation. Thus, it became evident that sufficient time to assure complete alum crystallization must be allowed to avoid subsequent formation of solids which would hinder solvent extraction operations.

Strontium-Barium Sulfate Coprecipitation

In Table IV are summarized the results of the initial coprecipitation evaluation studies. They indicate that, under boiling conditions, strontium, zirconium, and the rare earths are coprecipitated with the $BaSO_4$ precipitate.

Solvent Extraction

The laboratory scale solvent extraction study indicated that 99 per cent of the rare earths, ruthenium, zirconium, and niobium activities could be

TABLE IV.—Preliminary Coprecipitation Results in Which Acid $Al(NO_3)_3$ is Stirred 30 min at 100°C, Settled for 3 hr at 4°C, and Filtered

K_2SO_4 (g/100 ml)	Ba^{++} (g/100 ml)	Per Cent Removed					
		Sr^{89}	Ru^{106}	Ce^{144}	Y^{91}	Zr^{95}-Nb^{95}	Cs^{137}
6.0	0.5	95.8	10	99.0	48	63	0
6.0	1.0	98.0	11	99.96	92	75	9
6.0	1.0	99.8	—*	99.94	—	—	—

* No test made.

extracted into undiluted tributyl phosphate (TBP) from the acid $Al(NO_3)_3$ solution after a six-step extraction procedure. Table V summarizes the results of this laboratory study (7).

TABLE V.—Extraction of Major Long-Lived Fission Products into 100-Per Cent TBP (Cupferron and Fe Wire Added) (7)

Tracer	Cumulative Per Cent Removal after 6 Passes
Ce^{144}	99.93
Y^{91}	99.93
Ru^{106} (aged)	98.1
Ru^{106} (fresh)	99.4
Zr^{95}-Nb^{95}	96.2
Sr^{89}	8.5
Cs^{137}	0

Treatment Combination

The preliminary results, indicated in Tables III, IV, and V confirmed that each treatment by itself was ineffective for the removal of all the hazardous nuclides. For a 99.9-per cent removal of all activities (a 10^3 decontamination factor), a combination of these treatments was indicated.

The order of serial treatment of acid $Al(NO_3)_3$ waste was evaluated for one or more of the tracers concerned. Table VI lists these results. The data conclusively show that the optimum order of treatment is alum cocrystallization, sulfate coprecipitation, and solvent extraction. The excellent removals obtained for Cs^{137} and Sr^{89}, as well as the reproducibility of such results, favored the selection of this order of serial treatment to provide the most complete decontamination.

The final order of treatment is described below. However, before this regimen was determined, numerous comparative studies were made with modified treatment procedures.

1. Cesium-potassium alum cocrystallization. Dissolve 3.0 g K_2SO_4 in the warmed acid aluminum nitrate waste solution; add 15 g Na_2SO_4. Set in ice bath and stir for 60 min; allow for complete crystallization by maintaining a temperature of 0°C for at least three hours.

TABLE VI.—Exploratory Results of Serial Treatment Combinations on Decontamination of One or More Tracers from the Acid $Al(NO_3)_3$ Solution

Serial Treatment Combinations	Per Cent Activity Removed								
	Cs^{137}	Sr^{89}	Ru^{106}	Ce^{144}	Y^{91}	Zr^{95}-Nb^{95}	Cs^{137}, Sr^{89}, Ru^{106}	All Activities	
								Fresh	Aged
Solvent extraction +	—	97.1	—	—	—	—	98.0	96.0	98.3
Cocrystallization +	99.1	99.3	97.9	99.94	99.98	99.7	99.4	97.0	98.0
Coprecipitation	—	99.3	—	—	—	—	98.1	—	—
Cocrystallization +	—	—	—	—	—	—	—	99.6	99.3
Coprecipitation +	99.9	99.8*	97.9	99.98	—	99.8	98.3	99.8	99.1
Solvent extraction	99.9	99.7	—	—	—	—	99.8	99.9	—
Coprecipitation +	—	—	—	—	—	—	—	98.9	98.8
Cocrystallization +	—	99.3	—	—	—	—	—	99.7	98.6
Solvent extraction	99.0	—	—	—	—	—	—	99.8	—
Solvent extraction +	—	—	—	—	—	—	—	98.2	98.2
Coprecipitation +	98.8	98.9	97.5	99.95	99.94	98.5	—	98.8	98.0
Cocrystallization	—	—	—	—	—	—	—	—	—
Cocrystallization +	—	—	—	—	—	—	—	—	99.2
Solvent extraction +	99.8	99.1	—	—	—	—	—	99.6	99.1
Coprecipitation	—	—	—	—	—	—	—	—	—

* These values represent replicate determinations.

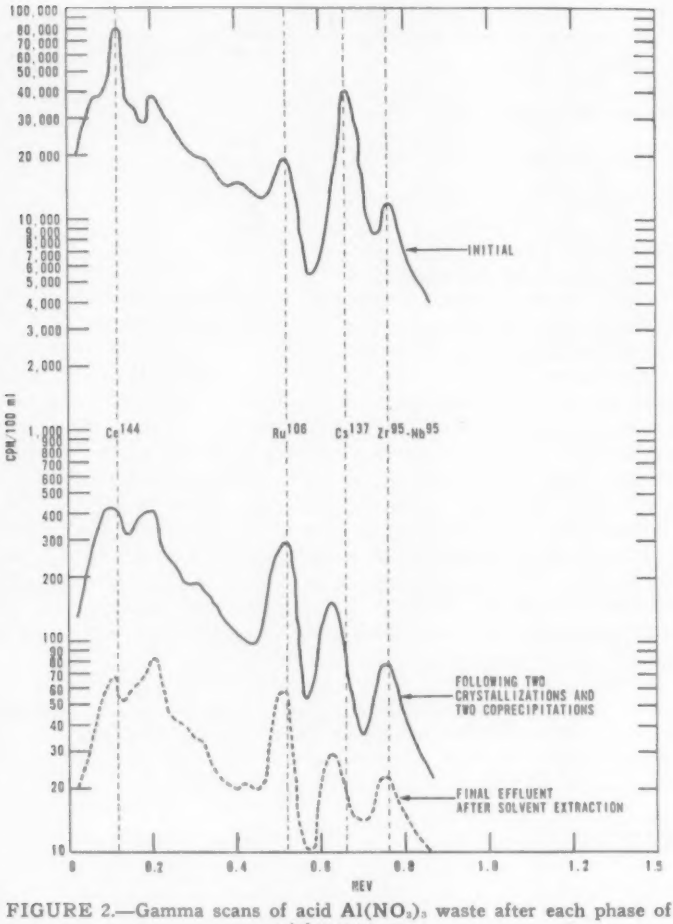

FIGURE 2.—Gamma scans of acid $Al(NO_3)_3$ waste after each phase of serial treatment.

2. Strontium-barium sulfate coprecipitation. Dissolve 6.0 g K_2SO_4 in boiling potassium alum filtrate. Add 15 ml $Ba(NO_3)_2$ solution (1.0 g Ba^{++}) and stir for 30 min on the hot plate. Maintain constant solution volume by addition of distilled water until precipitation is complete. Settle for at least three hours at 4°C before filtering.

3. Solvent extraction. The six-pass extraction procedure using a 20:1 aqueous to organic ratio and a 15-min shaking time has been described previously (7). The unextractable fractions of the Zr^{95}-Nb^{95} were converted to the extractable form by complexing with 1:500 ratio of 6-per cent cupferron, and following two extractions with TBP equilibrated with 1.6 M $Al(NO_3)_3$, the Ru^{106} was extracted after conversion to the nitrosylruthenium trinitrate by 20 mg of Fe wire in the 100-ml solution. Inasmuch as the rare earth activities are readily extracted into TBP, the final steps were for additional removal.

Discussion

From the data, it is evident, that the Ru^{106} removals were neither satisfac-

tory nor reproducible. Because of the complex chemistry of ruthenium, a study (7) had previously been made to determine the effect of solution "aging" prior to treatment. This study showed that ruthenium is converted to the extractable form (nitrosylruthenium trinitrate) (24) on standing in the acid nitrate medium, and that completeness of ruthenium removal is directly related to the length of standing time. The fraction of ruthenium converted could be further increased by boiling, or by heating with reducing metals.

Approximately 2×10^6 dpm of each of the critical nuclides was added to an acid $Al(NO_3)_3$ solution. After 30 days' storage, similar combinations of the serial treatments were evaluated on 100-ml aliquots. The conclusion to be drawn from the data in Table VI is that the most satisfactory order of treatment is cocrystallization, coprecipitation, and solvent extraction, even though a fraction of some individual activities remains.

As depicted in Figure 2, the peak at 0.52 Mev, representing the Ru^{106}-Rh^{106}, is most prominent, and indicates that even after 30 days' "aging" a fraction of the Ru^{106} is in an unextractable form and remains in the aqueous phase. Although peaks for the other gamma activities are visible in the spectra of the treated effluent, they are not as significant as the Ru^{106}-Rh^{106} peak. Considering its counting efficiency and noting the height of its photopeak, it is evident that ruthenium was the major activity remaining in this effluent.

The above conclusion was substantiated when this treated effluent was again subjected to alum crystallization, sulfate precipitation, and solvent extraction to ascertain which treatment gave the highest removal of activity. Neither the crystallization nor precipitation steps effected a decrease in activity; a repeated boiling and reducing step before solvent extraction caused almost complete removal of Ru^{106} as evidenced by the reduction of the height of the Ru^{106}-Rh^{106} peak to just above background, as shown in the final effluent spectrum in Figure 2 (dashed curve).

When the relative concentration of each of the fission products in the processed reactor fuel waste is taken into consideration, a weighted value for total decontamination by serial treatment can be calculated. Such a compilation has been made, and is shown in Table VII.

Although the total decontamination of 99.72 per cent by the indicated serial treatment falls short of the 10^3 plus decontamination factor considered essential before ultimate waste disposal, additional decontamination can be achieved by repeating the individual steps. The values given are for a single serial treatment for each of the critical fission products. It was ascertained earlier that with three successive alum crystallizations using 1–2-mc quantities of cesium-137 tracer, 99.9989 per cent of the cesium activity was removed. Similarly, with sulfate precipitation and solvent extraction, removals greater than those reported were obtained with repeated treatments. Lowe *et al.* (25) reported that although a single serial treatment provided a dilution factor of 5×10^2, this dilution factor could be increased to 10^5 with a 3-cycle process.

However, the order of serial treatment cannot be altered. Thus, to obtain a greater Cs^{137} decontamination, the second and later crystallizations must be performed prior to the other steps of the serial treatment. In the same manner, strontium was coprecipitated several times to assure greater than the 99.8 per cent obtained from a single treatment, but these precipitations were effected after the alum crystallization and prior to the solvent extraction step.

Unless reagent costs become consequential, such repeated treatments will

attain the degree of decontamination required before ultimate disposal, and the more hazardous fractions in the waste can be segregated. By reducing the cesium and strontium to less than 1/20 of the original volume for storage, the time required for containing the shorter-lived and less hazardous fission products can be reduced more than tenfold. A period of about 20 years has been suggested by Burns and Glueckauf (3).

Evaluation of the effectiveness of added carriers and Al^{+++} before or after each phase of the serial treatment has been reserved for possible future consideration. This modification could be of much importance in the crystallization and precipitation techniques and introduces the possibility of reversal of the treatment order. However, in the comparative studies it was evident that a reversal of the order of treatment results in lower total strontium removals. In this case, strontium removals may be improved with subsequent carrier addition.

The methods and efficiencies of stripping the fission products from 100-per cent TBP to permit reuse have been reported (7). The reversibility of the reaction by which the rare earths, ruthenium and zirconium-niobium, were extracted into the organic was demonstrated by serial application of concentrated HNO_3, dilute HNO_3, dilute HF in dilute HNO_3, and distilled water. Table VIII contains the results of stripping all activities from tributyl phosphate by serial back extraction of the four above-mentioned solutions. Since more than 99 per cent of all activities were stripped from the organic, this tributyl phosphate was subsequently equilibrated and employed in waste treatment solvent extraction studies. No attempt was made to ascertain radiation damage to the TBP because of varying opinions as to the significance of a high radiation field on the efficiency of a solvent extraction column. Nevertheless, with the three-stage serial treatment as proposed, there is an appreciable decrease in radiation after elimination of the cesium and strontium activities.

This reclaimed organic was employed in comparative solvent extraction studies, and no significant efficiency losses were evident after a single reuse. Whether there would be a significant decrease for future extractions was not investigated.

TABLE VII.—Weighted Removal of Fission Products from Acid $Al(NO_3)_3$ Solution by Serial Treatment

Activity	Fraction of Total Activity	Per Cent Removed by Treatment	Weighted Fraction Per Cent Removed by Treatment
$Sr^{89,90}$	0.183	99.8	18.27
Cs^{137}	0.001	99.9	0.10
$Y^{90,91}$	0.073	99.93	7.29
$Ce^{141,144}$	0.429	99.98	42.89
$Ru^{103,106}$-Rh^{106}	0.084	97.9	8.22
Zr^{95}-Nb^{95}	0.230	99.8	22.95
Total	1.0	—	99.72

TABLE VIII.—Stripping of All Activities from Tributyl Phosphate by Four Equal Volume Passes with Concentrated HNO_3, 0.1 M HNO_3, 0.1 M HF in 0.1 M HNO_3; and Distilled Water; Shaking Time of 30 Min per Pass

Initial Activity (cpm/ml)	Final Activity (cpm/ml)	Per Cent Activity Stripped From Organic
102,000	430	99.5
15,000	131	99.1
53,000	310	99.4
375,000	715	99.7

Summary and Conclusions

An effective method for removing all of the long-lived hazardous fission products from a simulated acid aluminum nitrate fuel processing waste has been presented. By combining cocrystallization, coprecipitation, and liquid-liquid extraction, the cesium and strontium activities can be segregated from the other fission products on potassium alum and barium sulfate,

respectively, while the rare earths, zirconium, yttrium, niobium, and ruthenium can be removed into undiluted tributyl phosphate. Prior treatment to convert the last two elements into a more extractable state is described.

This serial treatment has the following three-fold value:

1. Repetition of each stage permits a greater waste decontamination, provided the order of treatment is maintained.

2. Physical segregation of the two more hazardous and longer-lived nuclides, strontium and cesium, from the other activities produces at least a tenfold decrease in storage time of the remainder, provided that the dilution factor obtained will remove the significant concentration of these radionuclides.

3. The decrease in volume and activity of the waste reduces the heat problem significantly by eliminating the need for cooling facilities in the tanks, and results in more economical storage.

Limitation of laboratory shielding facilities prevented a high-level pilot plant study to procure more valid and statistically significant waste treatment data. With the exception of Zr^{95}-Nb^{95} (purity 97 per cent), the shipping inventory showed > 99 per cent radiochemical purity for all tracers used. These two factors have a considerable effect on the final result. Although they may have been inconsequential in the comparative study, they were significant in the attempt to arrive at a method capable of effecting a 10^3 or greater decontamination on the processed fuel waste.

This method, which retains the fission products in a specific area where their fate can be controlled, is vastly preferable to dispension techniques. The hazardous radioactivity, thus immobilized, is maintained in such a state that future use of the specific fission products can be expediently accomplished.

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COOK NEW BDSA ADVISER

James B. Cook, Jr., Sales Manager, General Products Division, Hays Manufacturing Co., Erie, Pa., recently was named Assistant Director for Mobilization Planning of the Water and Sewerage Industry and Utilities Division, Business and Defense Services Administration, U. S. Department of Commerce. Mr. Cook (right) is shown being sworn in by BDSA Administrator, William A. White, Sr. Walter L. Picton, Director of the Division, is in the middle.

MINE DRAINAGE CONTROL IN INDIANA *

By O. H. Hert

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The practice of controlling drainage from strip mine operations in Indiana started about thirty years ago when progressive mine operators started flooding final cuts where practical and reforesting the spoil banks. During the late thirties, when the mine sealing program was in operation under the sponsorship of the Indiana State Board of Health and the U. S. Public Health Service, earth dams were constructed to flood sulfuritic material in several areas that were producing acid mine drainage. Later investigations of the drainage from these flooded areas indicated an improvement in water quality.

The success of this program set the stage for additional work in this field: here was proof that something could be done to abate the pollutional effects of mine drainage. In addition, the water areas formed behind the dams and the reforesting of the spoil banks provided recreational areas. Over four thousand acres of stripped land are now utilized in the Indiana State Park and Forest System; recreational areas and subdivision developments utilize additional acreage, particularly in areas where lakes were formed.

Cooperative Program

In the late forties, the Division of Sanitary Engineering of the Indiana State Board of Health, the Indiana Stream Pollution Control Board, the Indiana Coal Association, and mine owners and operators began a cooperative program for the abatement of the pollutional effects of mine drainage. The Indiana Stream Pollution Control Law, Acts of 1943, as amended, provides that said Board "shall have the power to require the sealing of mines causing, contributing or about to cause or contribute to a polluted condition of the waters of this State." In 1951, the Indiana General Assembly amended the Open-Cut Coal Mine Law to require the construction of earth dams in all last open cuts where formation of lakes would be feasible.

The primary emphasis on mine drainage control in Indiana has been directed toward strip mine operations. However, much time is spent with deep mine operators to require proper handling of gob material and sedimentation of coal washery wastes. As of June 1959, there were approximately 65,000 acres of strip mine land in Indiana and stripping is continuing at the rate of about 2,000 acres per year.

Basic Problem

No practical method has as yet been discovered for improving the quality of coal mine drainage once the drainage has accumulated excessive amounts of acid, sulfates, etc. The problem then is (*a*) to prevent or reduce the formation of pollutional material subsequent to discharge to the receiving stream, or (*b*) abate the discharge to the stream.

Chemical tests used to determine the quality of mine drainage include pH, total acidity, iron, sulfates, and hardness. The pH test may be used in the field as an indication of the acidity or alkalinity. It cannot be used for quantitative analysis. The other

* Presented at the Ohio Sewage and Industrial Wastes Treatment Conf.; Cincinnati, Ohio; June 17–19, 1959.

tests are all relatively simple laboratory procedures; however, as yet no quick field test to determine pollutional qualities is apparently available.

A substantial amount of research on mine drainage problems has been undertaken by private and public groups. The methods discussed in this paper are not original to Indiana. Much of the background material was obtained from the work of Braley (1), Hebley (2), and the Sanitary Water Board of Pennsylvania (3).

Mining Terms

Some of the terms used are peculiar to the mining industry; the following definitions are offered to help clarify the discussion:

1. *Spoil*—The overburden removed to expose the coal in strip mining.
2. *Gob or sulfuritic material*—The sulfur-bearing refuse accumulated in connection with coal recovery.
3. *Final cut*—The last cut or removal of overburden in a stripping operation.
4. *Rider vein*—A vein of unmarketable coal which may occur above or adjacent to a marketable coal. It often contains appreciable sulfuritic material.
5. *Preparation plant or tipple*—The washing and/or grading plant for processing of raw coal.

Source of Problem

Acid and other undesirable end products can be produced when sulfuritic material, air, and water are present. Except for the amount and character of the sulfuritic material, all of the factors influencing the production of mine drainage can, to some degree, be controlled. It is often feasible and proper to segregate and isolate sulfuritic material from air and water. It is usually possible and feasible to exclude water, or where it cannot be excluded, move it as rapidly as possible to minimize contact time with sulfuritic materials. It is often possible to reduce the air available by water flooding of final cuts and/or earth cover of the sulfuritic material.

Specific Problems

Open Pit Drainage

Surface water should be excluded from the pit by the construction of diversion ditches along the pit above the high wall. If a stream goes through a mine area, it should be diverted to prevent contact with sulfuritic materials. The working pit should be kept dry and any accumulated water be disposed of as rapidly as possible. When the final cut is completed and the mine is closed, provision should be made for future control of surface drainage. If drainage is permitted to flush out weathered sulfuritic material, the detrimental effect of the mining will continue for years.

Sulfuritic Material in the Pit and on the Spoil

Sulfuritic material should not be permitted to accumulate on the floor of the pit where it will be pulverized by machinery and trucks. Crushing exposes more material to oxidation and increases the pollutional effect of mine discharge. Sulfuritic material should be segregated and buried under clean spoil. In preparation for closing of a mine, if the final cut is to be flooded, the refuse and debris on the bottom of the final cut should be leveled prior to water flooding. Where it is not practical to flood, the refuse should be covered with dirt and the final cut graded to prevent water from pooling on or adjacent to sulfuritic materials.

Gob Haulage Roads and Gob Disposal

The improper disposal of gob from preparation plants is one of the largest sources of pollution from mine drainage in Indiana. The use of gob on haulage roads is discouraged and consideration has been given to prohibiting its use for this purpose if necessary. One satisfactory solution for

gob disposal is placing it in a pit below drainage and either flooding the pit, or covering the gob with well-compacted earth to prevent or minimize oxidation of sulfuritic material.

Underground Mines

When underground workings are broken into, the drainage should either be blocked off or carried away from present workings. When the final cut is made, the underground workings must be blocked to keep water from entering or leaving the underground mine.

Inadequate Construction of Dams and Spillways

In some instances dams are inadequately constructed and proper spillways are not provided; thus, construction work is wasted and the probabilities of acid drainage increased when the dam or spillway failure occurs. It is essential that the construction be properly engineered and carried out to insure against future washouts or failure of the control works.

Indiana strip mine operators in cooperation with the Stream Pollution Control Board have adopted many of the above measures to accomplish abatement of the pollutional effects of mine drainage.

Abandoned Areas

Work undertaken to control acid discharge from abandoned areas has shown that when dams are constructed to flood final cuts and cover sulfuritic material, acid discharges are reduced. In some instances it has been possible to construct dams so that there would not be a direct discharge to the stream.

For example, corrective work undertaken at one mine has controlled the discharge of acid drainage from about 2,500 acres of stripped land during times of low flow. The main problem remaining at this mine is that of flushing of weathered sulfuritic materials to the streams with runoff from abandoned gob roads. An experiment in which test stretches of gob roads are covered by approximately two feet of clay material shows promise of a way to reduce the pollutional effects of mine drainage from this source.

One project undertaken to control acid discharge from a mined-out area was the construction of a lake to collect acid drainage from approximately one square mile of stripped area. Surveys by company engineers indicated this work might be accomplished by construction of one dam downstream from all drainage without flooding all the exposed sulfuritic material. The company plan was approved by the Indiana Stream Pollution Control Board subject to the condition that, if this project did not abate the acid discharge, further corrective work would be required. Results of sampling of drainage from this lake are variable; however, samples collected in 1950 indicated a total acidity ranging from 300 to 400 mg/l while those collected more recently have indicated acidities from 700 to 1,400 mg/l. The iron content has increased from a range of 30 to 65 mg/l in 1950, to 90 to 120 mg/l in 1954–55. Practically the only advantage noted to date from the construction of the lake has been the reduced flow during hot dry months when evaporation from the water surface is prevalent. This project has pointed up the necessity of providing continuous cover for the sulfuritic material if the formation of acid discharge is to be abated. The company has undertaken a project in the past two years to improve conditions by the construction of small dams and earthen cover of exposed sulfuritic material upstream from the lake.

Evaluation of Program

It is hard to measure the success of the program in terms of reduction in the tons of acid discharged, because in many of the new mines control measures have minimized the formation of

acid during the operation, and mine closing measures are undertaken prior to leaving the area; thus there has not been a pollution problem. There are instances of acid drainage from old abandoned operations, while in the same general area newly closed mines are causing no trouble.

One coal company operating in Indiana has established a weekly sampling program to keep a check on the effect of their operation on the receiving streams. Samples are also collected and chemical analyses recorded of conditions in the streams prior to mining operations by this company. It is believed to be essential for each mine to maintain a continuous water survey for its own protection and for the protection of water resources now and in the future.

There still are problems caused by drainage from present and abandoned operations, both from surface and deep mines; however, if the pollutional effects of drainage from strip mine operations are controlled, a major portion of Indiana's mine drainage problem will be abated.

Summary

In summary, experience to date has shown that the pollutional effects of mine drainage in Indiana, particularly from strip mine operations, can be abated by proper planning prior to the opening of a mine so that surface drainage can be controlled, and by the institution of control measures during the operation and prior to the closing or abandonment of the mine. The abatement of acid discharge from abandoned areas is more expensive; however, if continuous cover can be provided for sulfuritic materials, either by water flooding or earth cover, the pollutional effects can be minimized.

Acknowledgments

Much of the success of the Indiana program is due to the cooperation of the mine operators and the liaison work of Mr. L. E. Sawyer, Manager of the Indiana Coal Association.

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33rd ANNUAL MEETING

WATER POLLUTION CONTROL FEDERATION

Philadelphia, Pa.
Sheraton Hotel

October 2–6, 1960
Convention Hall

INDUSTRY AND WATER RESOURCES *

By N. D. Griswold

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The subject of water resources is and has been of such importance that it has been intensively studied for many years, and there is a substantial amount of literature on the subject. For example, the U. S. Geological Survey and various state agencies have been and are continuing to collect and analyze factual information for many years, and this information is readily available.

Those intimately concerned with water supply and disposal problems recognize the importance of adequate and sustained water supply to satisfy the needs of the general population, agriculture, and industry—all claimants of water. However, it is believed that the general public is not adequately informed, and is not aware of the close relationship between water resources development and the success or failure of a civilization. It is a natural conclusion that protection and preservation of the basic water resource and its efficient use will become more important as the present population, agriculture, and industry expand.

Water Distribution

The unequal distribution of water resources throughout the United States, ranging from the arid desert regions of the West to the perennially flowing streams of the East, the irregularity of replenishment of the water resource, and the variability of the quality of the water resources, together with the appropriation of the limited supply by the early arrivals, have resulted in a very complex body of law differing from state to state and region to region, applying to the appropriation and use of water. In areas of limited water supply, water rights have acquired substantial value.

Use of water and the disposal of used water by industry generally are of such importance that they are matters of serious consideration in studies for any industry location and are of continuing importance to assure the uninterrupted supply for present and future needs. Industry today in its operations or in contemplating a new location must also consider the effect of its use of water on the water resource.

Water Resources and Cost

As a frame of reference, attention is called to two general facets of the United States water resource—total resource and cost of water.

The total resource is comprised of: (*a*) average annual precipitation of about 4¾ billion acre-ft, (*b*) the underground water resource, and (*c*) water in natural and artificial reservoirs.

The average annual runoff to the sea is about 1⅓ billion acre-ft.

The apparent average annual consumptive use by transpiration, evaporation, etc., is, by difference, about 3⅓ billion acre-ft per year.

Converting to more easily recognizable size, average annual replenishment rate is approximately 3,000 million gpm; the runoff to the sea is approximately 1,000 million gpm; and the consumptive use is approximately 2,000 million gpm. The total replenish-

* Presented at the 32nd Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Dallas, Tex.; Oct. 12–15, 1959.

able water resource is a constant, varying cyclically due to short and long climatic changes.

Unfortunately, average figures cannot be used in appraising the adequacy of a water resource or water supply for industrial purposes, and it is necessary to search much deeper into the available records to determine the minimum, maximum, and reliable quantities. All are familiar with the story of the man who could not swim and who drowned in the lake which was only six inches deep on the average. Intentionally or unwittingly, improper use of facts has often resulted in wide misunderstanding by the public of water problems.

The expression, "cheap as dirt," is familiar to all. A more appropriate expression might be "as cheap as water" when it is desired to express something of extremely low value. Today, fresh water can be manufactured by distillation of sea water at something less than $1 per thousand gallons. This is equivalent to less than 25¢ per ton. Potable municipal water is available quite generally under pressure on demand from a spigot at 20 to 30¢ per thousand gallons—equivalent to 5¢ a ton. Industrial water commonly costs not over 4¢ per thousand gallons. This is equivalent to 1¢ per ton. Irrigation water in the Texas-Louisiana Gulf Coast rice belt is available at about $12 per acre-year of irrigation; and if a farmer uses four acre-ft of water per acre of land, this works out to 9/10¢ per thousand gallons, or 1/4¢ per ton of water delivered to his land. Stored water for subsequent diversion has been sold in the range of $1 to $2.50 per acre-ft—equivalent to 1/10 to 1/4¢ per ton.

The agreement being considered between the City of Houston and the Trinity River Authority proposes contractual delivery of water at 6 ¾ mills per thousand gallons or 3/16¢ per ton. Large quantities of lowhead sea water can be delivered in favorable locations for 1 to 1½ mills per thousand gallons—equivalent to 1/32¢ per ton. These data should substantiate the opinion that "as cheap as water" is more appropriate than "as cheap as dirt." Equally, it should be agreed that when water is in short supply, it acquires a value completely at variance with established use patterns based on its normal low cost.

Industrial Location Selection

Attention is called in a little more detail to the two main areas of the water resources viewpoint from the standpoint of industrial management: (*a*) location selection factors, and (*b*) the existing situation after a location has been selected and the industry established. An industry selecting a new site of operations must consider many factors and each is of variable importance depending on the particular business. Among these factors are: (*a*) raw material availability and cost; (*b*) labor availability and cost; (*c*) climate and living conditions; (*d*) marketability of products to be produced; (*e*) cost of transportation to market; (*f*) availability, character, and cost of purchased utilities such as fuel, power, and water; (*g*) the political climate, including taxes, prevailing and likely to prevail at the site; (*h*) the availability and cost of the necessary real estate required; and (*i*) the waste disposal problems incident to the operations proposed. A similar list is valid and peculiar to each type of industry and to units within a given type of industry, and nothing short of a full consideration of all pertinent factors can assure a successful and continued enterprise. In the location selection factor list are included water and waste disposal. Contrary to general public opinion, it is believed that waste control and disposal should be considered of far greater importance than is commonly acknowledged and that water supply is conversely much less important than

is generally thought. To support this view, reference is made to the fact that Lake Superior is a tremendous body of marvelously pure fresh water having an average temperature of approximately 33°F. No substantial influx of industry has in the past or is now occurring in the Lake Superior region. Obviously, other factors than pure water are preventing large scale industrial development in the area.

Next, consider Southern California, with limited water resources. Very large industrial development has occurred in this area and is continuing, resulting in huge expenditures to transport over long distances the vast quantities of fresh water required by the industry, agriculture, and residents. Due to the continued growth of Southern California, governmental bodies are considering billion dollar expenditures to bring water from Northern to Southern California.

It may be that the ultimate example of the industrial development in the absence of water is the establishment, in the Middle East, of major refineries with adequate accommodations for personnel where there is no fresh water and the entire fresh water supply is obtained by distillation of sea water. Huge deposits of petroleum provide the incentive, regardless of the total lack of fresh water resources.

Evaluation of Location Factors

Continuing, consider the industrial viewpoint of water resources after an industry has established itself in a given area with large fixed capital investment and is in successful operation. If all the location selection factors previously mentioned were adequately considered and have proved favorable, if management is good, if the enterprise has contributed something of value to the public, it is a successful enterprise. In the original evaluation of the location, the water supply, if it was incidental, was probably obtained from a local municipal source. If of greater magnitude, the enterprise may have made original diversion from a source of supply such as a lake, fresh water stream, from underground strata, or in part, from a tidal source. The original valuation assumed growth of the enterprise and growth of the area. Presumably, also, the original evaluation adequately considered the disposal of the waste products of the enterprise and also the increasing waste disposal problems of other activities of the area. Even with the best of projections and estimates originally made, industrial management must review and adapt itself to the changing value of all the relevant factors affecting its success.

Consideration is given here only to the water resource factor and the relative value of this factor, as previously mentioned, varies widely. In the original evaluation, relative availability and cost will set a pattern for the design of the enterprise. Consider an industry locating on the Great Lakes, diverting directly therefrom. Adequacy of the water resource is practically limitless, and disposal of the effluent becomes an essential major consideration. Consider an industry located on Tidewater in an area of limited fresh water supply. Sea water is fully satisfactory and very low cost for all coolant purposes if proper provisions are made for use and for disposal of effluent. Consider an industry locating on a fresh water stream or over an underground supply without the advantages of limitless fresh or sea water supply. Continued operation of the enterprise is contingent on not only the industry's efficient and economic use of the available supply, but also on the efficient and economic use of this same supply by all other claimants. Such a situation, even with the best of initial provisions, requires continuous vigilance to assure a continued satisfactory situation. There is a common saying in Texas that "highority is better than priority," and water

rights must be continuously defended to be of value in areas where the appropriation theory prevails.

In each of the above situations, location on limitless fresh water, location on limitless sea water, or location on limited fresh water, requires, as an element of continued successful operations, the harmless disposal of effluent. Vast quantities of water are used by industry for cooling purposes only; and with location on bodies of water, consumptive use is negligible. Where bodies of water are inadequate in size, cooling water may be recirculated through cooling towers with consumptive use of not over 5 to 10 per cent of the throughput. A recent extensive experiment in West Texas on the use of Lake Colorado City as a cooling reservoir in connection with a large power installation, has indicated that radiation is a substantial factor in reducing the consumptive loss as compared with the operation of cooling towers (1). With proper concern for the problem, industry can reduce consumptive use. Recently, Noll (2) stated that all industries now withdraw approximately 111 billion gpd and only 2 per cent is used consumptively, 98 per cent being returned to some water course where it may be available for someone else to use. Again, it is emphasized that generalizations are dangerous and that certain industries use much higher proportions of water consumptively.

Economics of Water and Industry

Low cost of water has permitted industrial installations whose economy is based on this low cost. For instance, single pass cooling equipment with the discharge of the water to mix with contaminants without provision for reuse, when the installation is made, commits the industry to a course of action which cannot be changed without large expenditure for rearranging or providing additional equipment. An excellent example of the impact of high cost or low availability of water on industry is illustrated by the fact that the steel industry generally, where water is easily available, has been accustomed to using 65,000 gal of water for each ton of steel it produces; but good engineering, based on a meager and costly water supply, permits the Fontana, California plant of Kaiser Steel Corporation to operate on 1,400 gal/ton—a 46-fold reduction.

Low cost water affects its use. It has been the common experience of municipalities delivering unmetered domestic water that the installation of water meters and billing on the basis of use decreases the water requirement and has solved many critical municipal water supply problems. New York City's water supply, which in the recent past has been critical, would have been greatly alleviated by the general installation of water meters.

Irrigators of rice, in at least some areas along the Gulf Coast, use approximately four acre-ft of water per acre of rice. Two acre-ft are considered sufficient. Water is sold to the farmer on a unit area per year basis with little incentive for economy in the use of water.

Planning for the Future

Continued expansion of industry and agriculture, continued population growth, and movement of population to areas of less reliable or inferior water resources presages a continuing and growing crisis in the water supply problem, which will demand very extensive water conservation and supply works. Their magnitude is indicated in a report (3) in which it is estimated that the United States will have to expend something like $171 billion to meet the nation's water needs by 1975. Based on 1958 replacement cost, the United States already has nearly $179 billion invested in water development. An expenditure on the order of $171 billion over the next 15 years must be paid out of taxes, and industry's share of the tax bill is and will be large. Industry has a vital stake in efficient

use of the water resources to minimize future expenditures.

It is believed that the most economical method of providing the water requirements of the future should allow for payment by all the water users of sums adequate to cover the cost of operation and amortization of the facilities providing the water. With no charge or a charge wholly inadequate to cover the cost of the water supply, inefficiency in its use, if encouraged, cannot but in the long run result in an overdraft on the available supply.

With the future potential strain on water resources, even with the expenditure of vast sums, efficient use of the water available is essential. In the past with plentiful water supplies and relatively little industrialization in an area, waste disposal was easily accomplished by dumping in the nearest body of water, thus diluting the waste and depending on natural processes to restore the water to usable condition, for reuse by the next claimant. With increasing use and increasing density of industry and population, many areas have experienced overloading of streams with waste discharges and have had to adopt stringent regulations and require installation of waste disposal plants so that returned water approximated usable water. Industry belatedly but thoroughly is becoming convinced that it must definitely control its waste disposal problem and that it cannot defile the general water supply. This recognition is not yet complete, but it is believed that industry is seriously disposed to be a good neighbor and do its part in assuring that water once used will be satisfactory for reuse many times.

Municipalities are major claimants of the water resource, and water supply and waste collection systems have generally been installed in periods of plentiful water and available diluent. Increasing population density and use of water in many areas have passed the point where municipalities can satisfactorily dispose of their municipal wastes without treatment. Industry does and should assist and encourage municipalities to dispose of their wastes only after proper treatment and should also diligently consider the reuse of municipal wastes as a source of industrial water supply. This has been accomplished a sufficient number of times to prove that the practicality is without question.

Summary

In conclusion, emphasis is repeated that the water resources problem from an industrial viewpoint is complex, but understandable. A successful business enterprise must give adequate consideration to provisions for a proper water supply not only initially, but throughout the reasonable future with due allowance for not only the industry's growth but the area's growth. In the future, industries should, through any appropriate means, encourage the understanding of the total water resources problem, so that the general population, the agricultural, and the industrial claimants to the water resource realize that the water resource is limited and that it is imperative for all claimants to exercise increasing respect for its value and need for economical and reasonable use with due consideration for the last user.

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Stream Pollution

COMPUTATIONAL AIDS FOR FORECASTING WATER QUALITY

By E. F. Gloyna and R. S. Schechter

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A great variety of complex problems are encountered in water quality studies and many of these can be evaluated through the use of high-speed electronic computational techniques. This approach is not necessarily new, for similar techniques have been used to prepare flow hydrographs and provide hourly or daily stream-flow routing data. Water quality problems, however, have not been studied as extensively. It is expected that water will continue to be the major resource in many areas, and much more emphasis will be placed on knowing more about the quality patterns characteristic of a particular basin.

Engineers must begin to put quality evaluations in their proper perspective. The future quality of a surface water will be a function of natural pollution as well as the degree of domestic and industrial development, the latter obviously directly related to the available surrounding resources. Furthermore, future quality degradation may not be measured necessarily by such age-old yardsticks as BOD and temperature. Historical BOD data and other recognized pollution indicators may have only limited value in a matter such as a comprehensive water reuse program.

Multi-use water development programs for entire river basins, particularly where the supply of water is limited, may very well begin by answering a variety of "what if" questions regarding quality. For example, what will be the chloride content of a stream if a series of impounding reservoirs are built or if the industrial environment changes and a million additional people contribute their waste to the river basin? The latter population increase is not an unrealistic assumption where river basins cover a large area rich in natural resources.

The Problem

This paper describes how the buildup of chlorides can be followed in a reservoir under certain conditions of water reuse. The purpose is to demonstrate how well-known numerical techniques can be used to evaluate reservoir parameters under conditions which have been specified a priori. The computational techniques are not intended to predict future events. The results based on these historical data, however, do provide a certain degree of statistical confidence for future planning. The technique of computation, if programed on an automatic computing machine, can be repeated on frequent intervals using appropriate flow and rainfall data. Sufficient data of this type can help materially in establishing more efficient reservoir operations.

The model chosen to demonstrate the chloride buildup in a reservoir consid-

TABLE I.—Nomenclature for General Model

Inflowing Streams		Reservoir		Outflowing Streams	
Flow (acre-ft/yr)	Cl^- Conc. (lb/acre-ft)	Volume (acre-ft)	Cl^- Conc. (lb/acre-ft)	Flow (acre-ft/yr)	Cl^- Conc. (lb/acre-ft)
U_i	C_i	V	C_R	U_i'	C_i'

ers rates of inflow and outflow of various streams, concentrations of chlorides of various inflow and outflow streams, the concentration of chlorides in the reservoir as a function of time, and the volume of the reservoir as a function of time. Nomenclature for inflowing Streams 1, 2, 3, . . . , n and outflowing Streams 1, 2, 3, . . . k are shown in Table I.

The simplest model having the conditions imposed above would be one where the contents of the reservoir are uniform, i.e., there are no concentration gradients within the reservoir. The validity of this assumption will be discussed in a subsequent section.

A volumetric balance throughout the reservoir can be described mathematically. The inflow volume during a small time interval Δt is equal to $\sum_{i=1}^{i=n} U_i(\Delta t)$ and the outflow in the same interval of time is $\sum_{i=1}^{i=k} U_i'(\Delta t)$. The difference between the inflow and the outflow serves to increase or diminish the volume of water stored in the reservoir by an amount ΔV. Hence Equation 1 describes the limit as Δt approaches zero:

$$\frac{dV}{dt} = \sum_{i=1}^{i=n} U_i - \sum_{i=1}^{i=k} U_i' \ldots\ldots (1)$$

Similarly the concentration balance can be shown to be:

$$\frac{d(VC_R)}{dt} = \sum_{i=1}^{i=n} U_iC_i - \sum_{i=1}^{i=k} U_i'C_R \ldots (2)$$

or

$$V\frac{dC_R}{dt} = \sum_{i=1}^{i=n} U_i(C_i - C_R) \ldots\ldots (3)$$

Example

To more clearly define the numerical techniques available, a not too unrealistic city and reservoir system were put together as shown in Figure 1. A reservoir having a capacity of 1.8 mil acre-ft was chosen. This reservoir system in combination with a well field would presumably provide the water for this typical industrial city.

In this case, the assumption is made that the inflow to the reservoir includes part of the well-treated sewage from the same city. Normally, the sewage would constitute a minor part of the total flow into the reservoir, but historical runoff records indicate that there will be times when the sewage effluent may be a significant fraction of the flow. One of the "if" questions which arises after considering such a proposal is the possibility of chloride

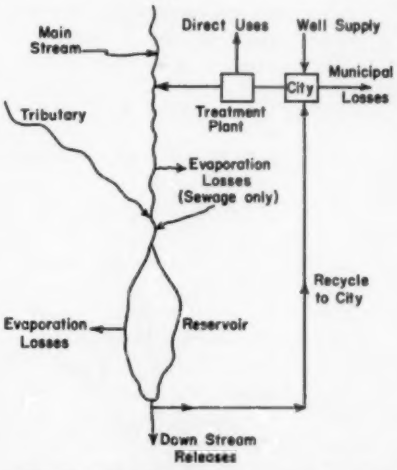

FIGURE 1.—Schematic layout of water supply and reuse system.

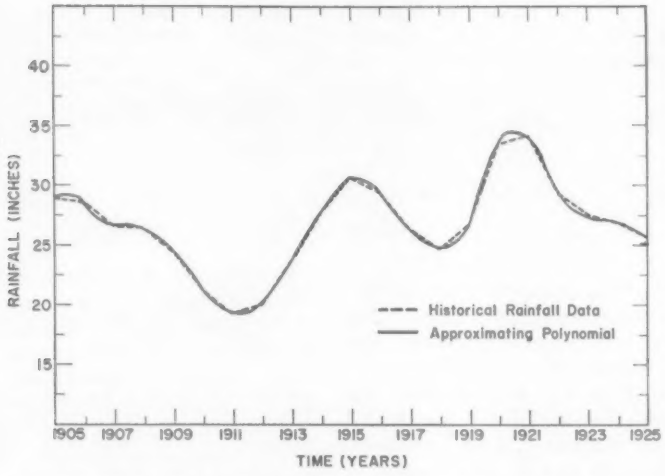

FIGURE 2.—Comparison of actual rainfall with results from approximating polynomial.

buildup in the reservoir. It goes without saying that sewage and the related water treatment processes must and can be modified to treat the organic wastes and other contaminants.

This possibility of excessive chloride buildup in the reservoir during periods of low flow means the entire system must be examined critically. To do this, historical rainfall and runoff data were plotted as shown in Figures 2 and 3. These data include samples which are representative of those which would occur during a severe drought, but such graphical representation is not in satisfactory form for general

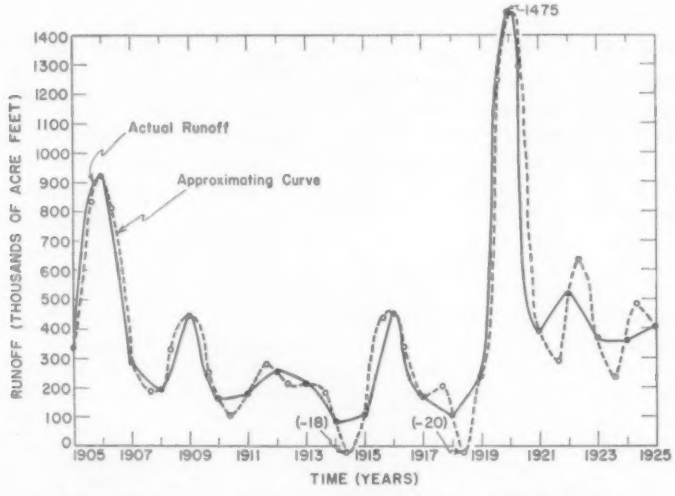

FIGURE 3.—Comparison of actual runoff with results from approximating polynomial.

numerical computations. The curves in Figures 2 and 3 may be more conveniently expressed by the following harmonic series:

$$y = A_0 + \sum_{j=1}^{12} A_j \operatorname{Cos} jx + \sum_{j=1}^{11} b_j \sin jx \ldots (4)$$

Equation 4 is readily usable and the constants are easy to evaluate, providing points of equally spaced data are available. Coefficients are readily computed in accordance with procedures outlined in Scarborough (1). As shown in Figures 2 and 3, the approximating curves are in close agreement with actual data.

The municipal and industrial water requirements were assumed to be constant at 341,800 acre-ft/yr, with 117,800 acre-ft/yr supplied by an underground source. The flow from the reservoir to the city then amounts to 224,000 acre-ft/yr.

Since the chloride content of the well water is assumed to be about 30 mg/l, the "what if" problem evolves around the water-recycle program. Consequently, it is necessary at this point to assume a value which relates chloride buildup with time. For this problem, it was assumed that effluent from this particular sewage treatment plant contains about 90 mg/l more chlorides than the weighted average in the water supplied to the municipality. This incremental concentration (90 mg/l) is taken to be additive to the initial concentration irrespective of the influent concentration. Further increases in chloride concentration are obtained as a result of evaporation and transpiration. In this case, evaporation is dependent on the time of year and, hence, is also a time dependent function. Typical evaporation data resulting from river losses are listed in Table II.

TABLE II.—Evaporation from River

Month	Flow Lost (%)
Jan.	5
Feb.	8
Mar.	10
Apr.	12
May	15
June	20
July	25
Aug.	20
Sept.	15
Oct.	12
Nov.	10
Dec.	10

Stream losses are highly variable and depend on distance as well as many other local factors, but once evaluated, these losses also can be approximated by a harmonic function of the type expressed in Equation 4.

Since a portion of the water supplied to the city in this model is not returned to the reservoir through the river system, the chlorides contained in the unreturned water are also assumed to be diverted. This diversion of chlorides may not be necessarily permanent, but surface leaching and ultimate return to the river will occur only after the assumed drought is broken. Under normal rainfall and runoff, the accumulated chlorides, even if leached from agricultural land, will not cause a significant problem. The fraction, f, of the water returned to the municipality is again based on historical data, and for the example under consideration can be written:

$$f = 0.379 + 0.009\,z \ldots\ldots (5)$$

The term z is in. of rainfall.

The evaporation from the reservoir was assumed to be 5 ft/yr which is not unusual for certain areas in the Southwest. The exposed surface area enters into the calculation, and this can be determined under actual conditions. In this case the surface area, A, in thousands of acres, was presumed to be a power function of the volume V; thus, it is a factor which can be readily obtained. The particular relationship

chosen for this problem is shown in Equation 6.

$$A = 0.74V^{0.70} \quad \ldots\ldots\ldots (6)$$

The rate of evaporation at any instant was computed by multiplying the area by the evaporation rate.

The required down-stream release from the reservoir was assumed to be constant at 30,000 acre-ft/yr. This release factor could constitute another "what if" problem in itself and frequently is of greatest importance.

In this particular example, inflow and outflow all have been specified as time functions in equation form. The problem is now ready to be rewritten so that it can be assembled and processed by high-speed electronic computers. A brief summary of computing techniques considered in this example is given in Table III.

Computer Techniques

The numerical solution of simultaneous differential Equations 1 and 3 is not a difficult numerical problem. The Runge-Kutta method was chosen because of its simplicity, accuracy, and inherent stability. An excellent discussion of this problem is given by Hildebrand (2).

The numerical computations were separated into the various phases and each phase termed a sub-routine. The harmonic analysis instructions were programed as a sub-routine; i.e., one need only to refer to the address of the first instruction of the analysis procedure and to the address of the next instruction following the routine, to analyze the data and to return to the proper instruction. The computation of inflow and outflow rates and concentration was also programed as a sub-routine so that additional streams could be added or the method of computing a stream altered without disturbing the basic Runge-Kutta instructions. As actually programed, a total of 10 outflow and 10 inflow forms

TABLE III.—Summary of Computing Techniques

Stream	Method of Computing Flow Rate	Concentration
City supply	Constant @ 224,000 acre-ft/yr	Cl^- concentration always taken as equal to reservoir concentration.
Downstream releases	Constant @ 30,000 acre-ft/yr	Cl^- concentration always taken equal to reservoir concentration.
Evaporation from reservoir	Evaporation is assumed to be 5 ft/yr. Area computed from equation: $A = 0.74V^{0.70}$	Cl^- concentration zero for all times.
Runoff	Acre-ft/yr; data fitted by harmonic series for 24-yr period. This series used to determine runoff as time function.	Constant @ 30 mg/l.
Return to reservoir from city sewage treatment plant	A fraction of total supplied to city returns to river supplying reservoir. This fraction computed by Equation 5 with rainfall data being computed from harmonic series. Also considered is evaporation en route from city to reservoir.	Concentration is weighted average of two supply streams incremented by 90 mg/l. Also considered is evaporation en route from city to reservoir.

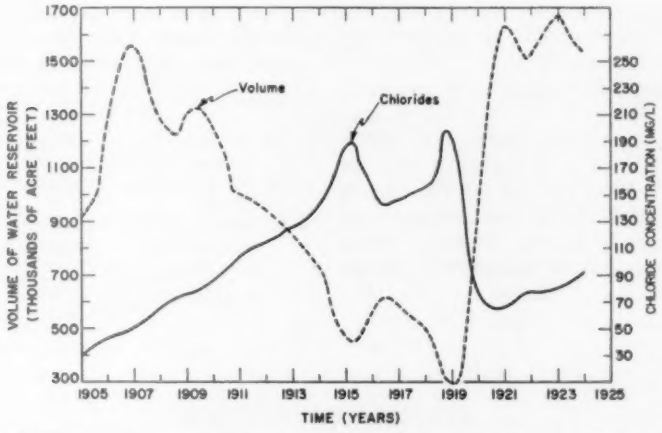

FIGURE 4.—Reservoir volume and chloride concentration as a function of time.

could be handled, together with the associated concentrations.

The program run was rather lengthy; 1 min 45 sec of IBM-650 computation time were required for each time step. Of course, the finer the increment, the better the accuracy, but the longer the computation period. As a compromise, time steps of 0.3 yr were used in obtaining the data discussed in the following section. Considerable savings can be effected by properly designing the problems, for IBM-650 computers rent for about $80/hr.

Discussion

The available dilution factor at any one time is largely a function of rainfall and runoff. In this problem, certain assumptions have been made regarding water demand, wastewater release, evaporation, chloride content, reservoir characteristics, and reservoir releases for purposes other than those cited. Figures 2 and 3 show comparisons of actual rainfall and runoff data with curves produced by approximating polynomials. In this case, a 24-yr record was used to illustrate the problem. The interval of time covered during this period includes both drought and above-normal rainfall.

The curves generated by the polynomials are sufficiently accurate for solving water supply and demand-type problems. To obtain results more accurate than those shown in Figures 2 and 3 would require an unnecessary amount of valuable computer time. However, by choosing a greater number of points along the actual curves, closer agreement can be obtained.

Once the necessary equations and coefficients have been developed, the chloride content can be evaluated for any time interval. Figure 4 shows how the chloride concentration increases from 30 to a maximum of 195 mg/l for the conditions stated in this problem. It is to be noted that volumes or concentrations shown in Figure 4 are "scaled points," i.e., if the chloride concentration had been more than 30 mg/l, the entire chloride-concentration curve would have been displaced along the ordinate accordingly. Likewise, any additional chlorides added as a result of recycling municipal wastes will increase the concentration in the reservoir. As long as the conditions remain unchanged, the chlorides will increase until an equilibrium condition is reached. If the flow increases or decreases, the chloride concentration

decreases or increases respectively, but in either case there is an apparent lag of about six months.

Complete flushing of the reservoir cannot take place, so a residual concentration greater than the initial amount of 30 mg/l always will be present. For example, if the system flushed itself or if a relatively large inflow occurred, the chlorides would be reduced, but if the inflow remained constant at a relatively high flow, the chloride concentration would again increase until equilibrium is reached.

References

1. Scarborough, J. B., "Numerical Mathematical Analysis." 3rd Ed., The Johns Hopkins Press, Baltimore, Md. (1955).
2. Hildebrand, F. B., "Methods of Applied Mathematics." Prentice-Hall, Inc., New York (1952).

MEETINGS OF INTEREST

May 15–20	**American Water Works Association,** Americana Hotel, Bal Harbour, Fla. Raymond J. Faust, Secretary, American Water Works Association, 2 Park Ave., New York 16.
May 19–21	**New York State Society of Professional Engineers,** Statler Hotel, New York. The New York State Society of Professional Engineers, Inc., 1941 Grand Central Terminal, New York 17.
May 22–26	**Air Pollution Control Association,** Netherland-Hilton Hotel, Cincinnati, Ohio. Arnold Arch, Executive Secretary, 4400 Fifth Ave., Pittsburgh 13, Pa.
May 24–27	**National Rivers and Harbors Conference,** Mayflower Hotel, Washington, D. C. William H. Webb, Executive Vice-President, Suite 523-A, La Salle Bldg., 1028 Connecticut Ave., N. W., Washington 6, D. C.
May 25–28	**Technical Progress in Sewage Treatment,** Katowice in the Sala Sejmowa of County Council, 25, Jagiellonska, Poland. Polish Society of Sanitary Engineers, Katowice.
June 5–8	**Seventh Industrial Waste Conference,** Honey Harbour, Ontario. Ontario Water Resources Commission, Parliament Bldgs., Toronto 5, Ont.
June 6–8	**Rudolfs Memorial Research Conference,** Rutgers, The State University, New Brunswick, N. J. Dr. H. Heukelekian, Dept. of Sanitation, Rutgers, The State University.
June 6–9	**Sewage Treatment Plant Operators Short Course,** Doane College, Crete, Nebr. Division of Sanitation, 1010 State Capitol Bldg., Lincoln 9, Nebr.
June 20–24	**American Society of Civil Engineers,** State Office Bldg., Reno, Nev. W. H. Wisely, Executive Secretary, 33 W. 39th St., New York 18.
June 26–July 1	**American Society for Testing Materials,** Chalfonte-Haddon Hall, Atlantic City, N. J. R. J. Painter, 1916 Race St., Philadelphia 3, Pa.

WATER RESOURCES AS VIEWED BY A STATE AGENCY *

By Milton P. Adams

Executive Secretary, Michigan Water Resources Commission, Lansing, Mich.

The national interest in water resources is well established at the federal level. While interests of this Federation and of the states are concerned primarily with water quality problems which make the activities of the Public Health Service the best known, there are the matters of basic data collection, weather and precipitation forecasts, flood and beach-erosion control, navigation improvements, and many other activities by other federal agencies. All are necessary to a state and the work of its people. These and other established functions generally involve the federal government as the major participant.

As regards relations between state and industry, the state agency in the water pollution control field knows that water is a necessity to many manufacturing processes; that the uses and requirements within industry vary with the product manufactured; that as a result of a management's water conservation policy or the lack of it, the amount varies greatly among makers of the same product. An extreme example is found in the industry-wide average of nearly 65,000 gal of water used per ton of steel produced as compared with the reported requirement of the Fontana plant of the Kaiser Steel Company in California of 1,100 gal per ton.

There are several reasons why this writer is unable to present an *average* state viewpoint on water resources: first, there are encountered fundamental differences in court-made water doctrines which divide the states into two major groups—that of "appropriation" for the Western states and the "riparian right of reasonable use" for the others. Second, there are differences in procedural methods and administrative organization in state laws on water pollution control. Third, a state's view is bound to be influenced by the uses that rate highest priority within a given state administration at a particular time. Finally, the generosity or scarcity with which nature has provided the various states with a water resource endowment makes the problem of use and conservation look different to nearly every state agency.

A special challenge is thrown down because those in the every-day pursuit of better sewage and waste treatment are being asked to improve their perspective of the entire field of water resources conservation. Of this, of course, wastewater treatment is but one necessary part. But what are the other facets that might simplify or render more effective this problem of restoring, maintaining, and even adding to our water resources reserve?

Future Conditions

The state agency's representative must in general take things as he finds them. Normally, he has no say in the location of a new industrial plant or the expansion of an old one. Even where he can sense that disregard of the water-availability factor will make a tough job more difficult and expensive to solve, the state's man must generally hold his tongue unless asked for

* Presented at the 32nd Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Oct. 12–15, 1959; Dallas, Tex.

advice. Perhaps the greatest improvement made in the Michigan law 10 years ago tends to dissolve this handicap.

When a new or expanded use of the waters of the state is to be made for waste disposal purposes, a simple statement is required to be filed with the Michigan Commission. The safe limit of additional use is determined by the staff, following which there is consultation and generally agreement with management in advance of Commission adoption of an order. This order establishes the allowable conditions of future use of the receiving waters.

To arrive at this end, a vigorous, searching attempt must be made to answer the following questions:

1. Can sewage and waste treatment be relied on to re-create a new water resources reserve capable of serving all future needs?
2. Will current treatment horizons limit future growth and development?
3. To what extent will water conservation by industry aid in solving water resources problems?

Question 1

Now to Question 1: all state agencies are reportedly engaged in the attempt to bring their municipal sewage and industrial waste problems under control. There is program assistance for state and interstate agencies and construction grants for cities through the Public Health Service, not to mention counseling and research. Now and then a dilatory interstate problem brings federal interests to the fore, but, so far, these instances have been few.

Faithful collection, thorough treatment, and a reasonably adequate dilution water with an assist from nature before the next use is made, is what all state agencies would like to see. But as population and industry expand, the water use–recovery cycle is subjected to more and more interference.

From the Sept. 1959 issue of the *American Engineer,* there is a reminder by engineers of the U. S. Geological Survey that the U. S. will need nearly 600 bil gal/day to meet its domestic and industrial requirements in 1980. That's 2½ times the present demand estimated at 240 bil gal/day. The records indicate the country got by nicely on only 40 bil gal/day in 1900.

From this article it would appear that approximately 100 bil gal/day represents the total of industrial and public water supplies of the Nation as of now. After use, this may well represent the amount of sewage and industrial waste to which Dahl (1) of the Public Health Service referred last year at a Midwestern conference. Dahl stated the case for the part which sewage and waste treatment can play in maintaining the water resources bank or reserve of a state or the Nation:

> Here on earth, pollution control, the Public Health Service believes, offers the greatest opportunity to conserve the largest amount of the Nation's water supply. Pollution control makes the 'used' water supply of a city or industry suitable for use again by another city or industry. We know of no other way in which water in vast quantities can be made of a quality suitable for use over and over again as it flows from city to city, from industry to industry and from farm to farm. Furthermore, unless water is of a suitable quality, it does little good to retain it in reservoirs, control its evaporation, or convey it by means of engineering works to water-short areas. Pollution control is a necessary, valuable and economical supplement to other water conservation measures.
>
> When the demand for water exceeds the supply, the only way needs can be met is by reusing the same water over and over. To be reusable, however, the water must be of the right quality as well as the right quantity. We keep water reusable by providing adequate pollution control measures.
>
> It is generally agreed among water supply experts that the Nation's water needs can best be served by controlling pollution to permit the repeated reuse of the same water as it moves from source to sea. More 'new' water can be added to the Nation's water reserve by controlling pollution than by any other means.

Now, all realize, it is believed, that even with effective treatment of sewage and industrial wastes by existing methods, there will be much to be desired as far as quality is concerned.

It is the author's understanding that present knowledge of sewage and waste treatment fails, for instance, to deal adequately with the waste detergent problem—the removal or neutralization of alkyl benzene sulfonates. Further, other chemical end-products are imparted to industrial wastes by the manufacture of synthetic fibers, plastics, insecticides, industrial solvents, and high-energy fuels which are not entirely removed in the treatment process. Too large a percentage of dissolved solids carry through to the finally treated effluent despite 95-per cent removals of BOD.

The raising of sewage and waste treatment efficiencies beyond present removal horizons is a "must" for many cities and industries, particularly those which can never expect to enjoy an adequate supply of diluting or receiving water.

Question 2

The answers to Question 2 so far encountered are both "No" and "Yes." Chicago said "No" in 1959—"all we need is more water from Lake Michigan—on a trial basis!" The Lake States and Canada say, in effect, "Yes, Chicago you are through growing if to do so you propose to divert more of that magic water from Lake Michigan!"

Despite the commendable 90-per cent purification of the Sanitary District's sewage, a series of 24 colored slides was shown before the Senate Public Works Committee on July 14, 1959, which pictured overflows of sewage, industrial waste, and sludge liquors entering District waterways in Apr. 1959. Ground garbage-type refuse, oil residue, and human flotsam were pictured "riding" unhindered on their so-called Sanitary and Ship Canal.

Whether "those colored slides were murder" as Sen. Paul Douglas was heard to exclaim following the Public Works Committee hearing, H.R.1, the diversion bill, was last reported slumbering in the Senate Foreign Relations Committee.

Faithful collection of all Chicago-area sewage and industrial wastes with treatment efficiencies increased another five points along with disposal of its sludge burden would undoubtedly help to reconcile the present issue between the states. But it would not eliminate the need for research that would demonstrate the extent and character of such additional remedial measures that may be in order there. Smaller but important problems elsewhere demand an answer also. Only by traveling the avenues of basic and applied research, employing, perhaps, wholly new concepts of sewage and waste treatment, can these dilution-short problems be solved or a small margin of water resource made available to support future growth and development.

The Public Health Service has been attempting to meet this need for many years, through research it sponsors and by its own forces. All that's needed is time and money! Here is a real challenge to researchers and grist for them to grind.

Another example of the need of more applied research comes from Michigan. With some preliminary research accomplished and more under way, future expansion of the Kalamazoo valley paper industry hangs in the balance. The efforts of two industry-sponsored committees organized a little over a year ago may determine whether future growth is possible and, if so, under what conditions. If a remedy is not found, the Commission faces the necessity of adopting further restrictive measures to reduce stream loadings, and managements can face the probability of damage suits. The pulp and paper mill industry of Michigan had its start in this valley. It

TABLE I.—Water Reuse by Industry

Industry	Reuse (%)
Apparel and textiles	14
Autos and aircraft	25
Chemicals and drugs	35
Foods and beverages	22
Iron and steel	25
Leather	12
Lumber and furniture	23
Machinery and tools	15
Nonferrous metals	18
Optical and medical	21
Paper and pulp	52
Petroleum	98
Plastics	19
Stone and glass	25
Toys and sports goods	19
Miscellaneous	22

expanded its production over the years, now, 10 managements, controlling seventeen mills or "divisions," are involved. With all area cities and mills providing Commission-ordered sewage or waste treatment, the minimum natural flow of the river is sufficient to receive and assimilate without nuisance or downstream injury only about 40 per cent of the present waste effluent loading. At the May, 1958, meeting of the Commission, it was necessary to make the public statement that further plant expansion involving waste-load increases could not be expected to receive favorable staff recommendation.

In an effort to ease that situation, a Battle Creek–Kalamazoo River Inter-Municipality Study Committee, composed of municipal and industrial leaders, was formed, and a firm of consulting sanitary engineers was employed. Their assignment was to determine how much stream flow would be required to offset the existing stream overload, and what would be the capital cost to provide the necessary upstream storage for that purpose. A report was made early in Dec. 1958 which concluded that an investment of $27 million would be necessary to provide from 70 to 525 cfs (an average of 300 cfs) during the months of June through October. The seasonal increase was the amount deemed necessary by consulting engineers just to restore acceptable stream conditions with present waste loadings and without further waste disposal outlays or plant expansion.

Further consideration of the upstream storage proposal with its controlled discharge has been abandoned. It was the consultant's conclusion that secondary treatment of paper mill wastes could be provided for less than the cost of the water storage. The extent to which secondary treatment or other disposition of mill effluent can be utilized is being studied by the two technical committees previously mentioned. One represents 4 de-ink process companies in the valley; the other deals with a less severe problem created by the six other companies—board and specialty mills.

The first formal reports of these committees were made at the Sept. 1959 meeting of the Commission.

Question 3

An Industrial Water Conservation Conference was held in June, 1959, in Ann Arbor. It was attended by some 125 industry representatives, consulting engineers, and governmental people.

Judging from reports received, conservation efforts by industry are under way and bearing fruit. The second day's program was given over to testimonials on the effectiveness of water conservation measures practiced by various branches of industry. A spokesman for General Motors opened the conference with this warning: "Engineers must accept the challenge of making less water do more work in the manufacturing processes." The spokesman for the Ford Motor Company related that water conservation in their plants does three things: reduces water costs, sewage disposal costs, and waste treatment costs.

A table appearing in the periodical previously mentioned presents the result of a National Association of Man-

ufacturers' survey of percentage of water reuse by various industries (Table I).

To what extent water conservation within industry is offset by increased use as the result of plant growth and industrial expansion depends on the specific areas and perhaps states concerned. In any event, it is certainly a step in the right direction.

Conclusions

From the foregoing discussion it would appear logical to conclude: (*a*) that sewage and waste treatment as it is known today is not going to be sufficient in some locations to re-create a water resources reserve capable of meeting all public needs; (*b*) that to permit future growth and development, existing treatment horizons should be abandoned and a search begun for superior methods; and (*c*) that more and better water conservation by industry will aid in solving water resources problems for the user.

The challenge is upon everyone in the wastewater field if the Nation is to be best served. To judge past work in sewage and waste treatment just on the basis of public health protection provided, odor nuisance prevented, or fish and aquatic life protected is short sighted. It should be in terms of water resources salvaged and conserved for future uses and benefits.

This purpose is at the core of more and more legislation, even though it may be imperfectly expressed in current state and federal laws. None can afford to get so far in advance of the legislative mandates that the opposition can cut the "supply lines." On the other hand, leadership is called for by those most familiar with the means and mechanics of making less water do more work and serve more people.

Two important events of 1959 emphasize the timeliness of this program and the importance of water use and conservation. The first was the adoption by the Senate of S. Res. 48 (Apr. 1959), and the subsequent appointment of a Select Committee headed by Senator Robert Kerr of Oklahoma. This resolution includes an invitation to report on such daily work subjects as stream sanitation and wastewater salvage, as well as all other known water resources problems. Deadline date for this Committee's report is Jan. 31, 1961.

The second item is action taken by the U. S. Supreme Court this past summer (1959) to resolve long-standing water resources differences between certain Great Lakes states and the Metropolitan Sanitary District of Greater Chicago. On June 29, 1959, the Honorable Albert B. Maris, U. S. Senior Circuit Judge of Philadelphia, was appointed Special Master to conduct his own investigation of several issues previously reopened and now pending before the Supreme Court. He is to "hold hearings with all convenient speed and to submit such reports as he may deem necessary."

This is a regional rather than a national problem. It is one for the Court to decide rather than the Congress. Proponents of additional diversion have sought, so far unsuccessfully, to bypass the Court's restriction against additional diversion. Only future developments before the Supreme Court can determine whether and under what conditions more water may be taken from Lake Michigan for sanitation purposes.

Reference

1. Dahl, A., Paper presented at the 3rd Annual Water Disposal and Stream Pollution Conf. of the Western Petroleum Refiners Association; Oct. 1–2, 1958; Wichita, Kans.

THE OPERATOR'S CORNER

HIGH-RATE DIGESTER PERFORMANCE AT JAMAICA*

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The Jamaica Pollution Control Project is situated in the Borough of Queens on the northern shore of Jamaica Bay. It receives some 55 mgd of sewage from an estimated connected population of about one-half million people in a tributary area of 23,400 acres. The sewage is essentially domestic in character, although some industries are now concentrating in the Idlewild Airport area. The sewage is stronger than that typical of New York City because of lower water consumption and the addition of cesspool wastes from scavengers operating in the unsewered areas of Queens.

Description of Plant

The Jamaica plant, with a design capacity of 65 mgd, was placed in operation in 1943. Except for a short period of operation with step aeration, the plant has employed modified aeration with treatment efficiencies in the order of 75 to 80 per cent. The plant equipment includes sewage pumps, air blowers, gas-engine generators, and other mechanical accessories. The raw sewage is treated in two four-pass aeration tanks (each pass 320 ft long by 30 ft wide), and aerator effluent is settled in eight 120-ft diam circular clarifiers. Activated sludge is returned to the aerators by means of air lifts.

Excess sludge is concentrated in either the clarifiers (two being so connected) or in two 55-ft diam thickening tanks. Thickened sludge is pumped with difficulty because of long suction lines from the thickeners to the plunger-type pumps located in the digester gallery. Some overpumping of the thickeners, therefore, is required to maintain operation.

Sludge is digested in 12 80-ft diam digestion tanks with gasometer-type covers for gas storage. Each unit has a nominal volume of 130,000 cu ft, providing an over-all digester capacity of 3 cu ft/cap. Several years ago, external sludge heaters and recirculating pumps were installed to serve six of the tanks because of the inability of internal heating coils to maintain required temperatures. Essentially single-stage digestion was utilized; the addition of previously thickened excess sludge produces practically no supernatant liquor of good quality.

Conversion of Digesters

In 1955, the design of sludge digestion facilities for the proposed 310-mgd Newtown Creek plant came under

* Presented at the 32nd Annual Meeting of the New York Sewage and Industrial Wastes Assn.; New York, N. Y.; Jan. 20–22, 1960.

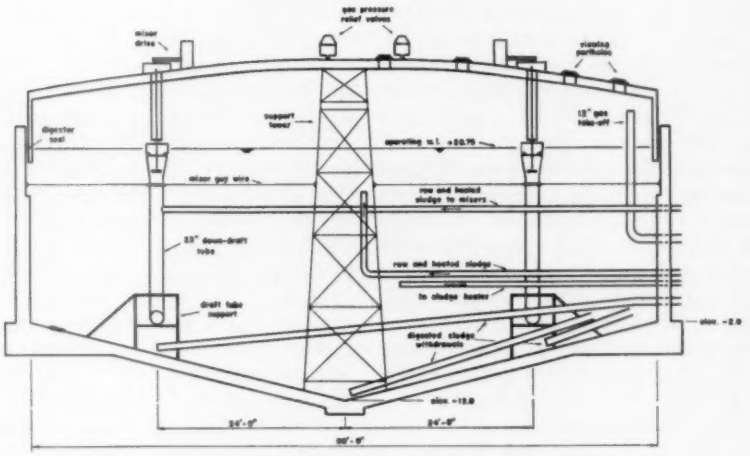

FIGURE 1.—Schematic drawing of high-rate digester.

consideration. The work by Torpey (1) (2) at Bowery Bay, using a pilot plant and a plant digestion tank, demonstrated that digesters could be operated at much higher solids loadings than current practice usually recognized. Faced with the predicament of wanting to apply this work to Newtown Creek, but lacking data based on plant-scale operation in a plant with the same treatment process, the Jamaica plant was chosen as the experiment station to satisfy the need. This plant uses the modified aeration process without primary sedimentation.

Four digesters were modified at a cost of $180,000 so that two could function as high-rate digesters and two as residual gas extractors. Digesters 11 and 12 were converted to high-rate units as shown in Figure 1. Each tank was equipped with four down-draft propeller mixers, with the draft tubes terminating at the bottom in a 90-deg elbow at right angles to the radius. Each tube is located 0.6 of a radius from the center of the tank. The mixers are driven by 10-hp motors and each has a capacity of 7,500 gpm when pumping clean water downward, providing a theoretical tank "turnover" of 30 min. The propellers may be operated upward for loosening debris from the blades. One mixer in each of Digesters 11 and 12 may be observed through glass-covered portholes placed in the cover (Figure 1).

Propeller mixers make it necessary to control closely the liquid level of the tank if effective recirculation is to result and scum is to be drawn into the draft tube. The level must not vary more than 3 in. from optimum. To attain this control, a sludge transfer box was provided with short, straight runs of pipe from the high-rate digester withdrawal lines to the overflow in the box and from the box to the residual gas extractors. The liquid level in the high-rate digesters is set by adjustment of variable-length sleeves on top of the overflow pipes. As raw sludge is pumped into the high-rate units, an equal quantity of digester contents flows into the box and thence to the extractors.

Four withdrawal lines are provided; one takes suction at the bottom of the cone, and the other three go to points 120 deg apart and 26 ft out from the center. The center drawoff is usually used in conjunction with a pump, but the outer drawoffs are gravity lines.

New 12-in. gas lines were provided to remove the larger quantities of gas expected from the high-rate digesters. A rotary-type positive displacement gas meter was provided for each high-rate unit, residual gas extractor, and waste line. This allowed measurement of the gas produced in each high-rate digester and its companion extractor.

A torque-flow pump was provided to remove undigested or high-ash sludge from the bottom of the digester cone. Sludge recirculation at a higher level was accomplished by having the sludge heater pumps discharge into the raw sludge feed line. The gasometer covers were rigidly anchored to the concrete and were reinforced to support the mixers and motors. They were protected against both high and low gas pressure by relief valves.

Operation of the High-Rate Digesters

The tanks were placed in operation in April 1958. At that time, Digesters 5, 6, 7, 8, 9, and 10 were in service. The high-rate units, Digesters 11 and 12, were filled with digesting sludge from the operating tanks. Raw sludge was first admitted to No. 11 on April 11 and to No. 12 on April 20, each receiving about 1/4 of the daily pumpage. Raw sludge additions were gradually increased until by May 15 they were receiving nearly the entire plant load. Approximately one month after seeding, the high-rate units were handling this load.

During the initial startup period, excess sludge was concentrated in the thickening tanks to simulate the proposed operation at Newtown Creek. The Jamaica thickeners, however, were not designed for the very heavy sludge which was occasionally produced and the drive mechanisms finally failed. After July 15, a final settling tank was utilized as a thickener.

Feed Schedule

The operating schedule was to pump sludge from the thickeners to the digesters at 3-hr intervals, each unit being fed for about 30 min. Each feeding represented about 1/16 of the total daily load. An equal quantity of the contents of each high-rate digester was displaced to its companion gas extractor. The increase in elevation of the extractor was used to measure the volume of sludge pumped into the high-rate unit. Twice a day, digested sludge was pumped from the extractors to storage. Each high-rate digester was recirculated from the bottom of the cone for about 2 hr a day. All sludge movements in and out of the tanks were carefully sampled.

Analyses for total solids and volatile content were performed on all sludge samples; pH, alkalinity, and volatile acids determinations were performed as required, as well as determinations of the grease in raw and digesting sludges and the CO_2 content of the gas. Daily records were kept of sludge volumes, temperature, and gas production.

The plan of operation was to feed the entire plant load, in equal portions, to the two high-rate digesters to demonstrate long-term stability at this loading. Progressively, greater portions would then be fed to Digester 11, moving in steps of 1/16 of the plant load and for a sufficient period of time to demonstrate stability at each level, until the limit of loading would be approached. As the load on No. 11 would increase, the load on No. 12 would correspondingly decrease. The results of this procedure for the period June 1958 through Oct. 1959 are shown in Table I*a*, which presents the data on sludge loadings for Digesters 11 and 9, and in Table I*b* for Digesters 12 and 10. Each pair comprises a high-rate digester and its companion residual gas extractor. Table II presents the analytical data for the liquor in the high-rate units and extractors as well as the volatile matter destruction. In Table III are the data relating to gas production.

TABLE I.—Digester Loadings

Year and Month	Raw Sludge				H-R Digester Loading				Transfer Sludge (1,000 lb/day)		Digested Sludge (1,000 lb/day)		H-R Digester Temp. (°F)
	Pumpage (cu ft/day)	Detention (days)	TS (%)	VS (as % of TS)	(1,000 lb/day)		(lb/day/1,000 cu ft)						
					TS	VS	TS	VS	Total	Vol.	Total	Vol.	
(*a*) Digesters 11 and 9													
1958:													
June	9,600	13.5	7.0	75.3	43.0	32.4	330	250	22.6	13.9	19.7	11.6	94
July	10,900	11.9	7.3	73.5	51.1	37.6	390	290	24.6	15.0	23.4	13.8	95
Aug.	10,600	12.3	6.2	74.8	42.5	31.8	330	240	24.7	15.1	23.1	13.5	95
Sept.	11,100	11.7	6.7	73.8	48.0	35.5	370	270	23.6	15.3	21.9	13.5	93
Oct.	11,000	11.8	6.8	75.5	48.0	36.3	370	280	25.8	16.3	22.9	13.7	92
Nov.	10,700	12.1	6.8	79.3	46.3	36.7	360	280	23.8	15.6	22.1	13.5	90
Dec.	10,900	11.9	6.4	79.3	44.6	35.4	340	270	22.9	15.2	21.3	13.1	92
1959:													
Jan.	11,600	11.2	6.3	81.3	46.9	38.1	360	290	24.7	16.9	21.5	13.9	93
Feb.	10,800	12.0	7.0	78.2	48.7	38.1	370	290	25.1	16.9	21.5	13.6	94
Mar.	12,300	10.6	7.1	77.8	55.7	43.4	430	330	28.7	19.6	24.3	15.4	92
Apr.	12,000	10.8	6.7	76.8	51.6	39.7	400	310	25.1	15.9	22.0	13.8	93
May	11,600	11.2	6.5	76.1	48.1	36.6	370	280	25.0	16.0	22.5	13.5	95
June	10,800	12.0	7.9	74.1	54.4	40.3	420	310	27.8	17.6	24.0	14.5	95
July	10,100	12.9	7.3	74.9	47.4	35.5	360	270	25.7	16.0	24.0	14.1	93
Aug.	10,400	12.5	6.8	73.3	45.2	33.1	350	250	25.3	15.9	24.2	14.2	92
Sept.	11,200	11.6	7.4	73.2	52.9	38.7	410	300	30.0	19.1	26.4	15.4	91
Oct.	13,600	9.6	7.2	78.2	63.1	49.4	490	380	34.1	23.0	30.9	18.9	92
Avg	11,100	11.7	6.9	76.2	49.3	37.6	380	290	25.9	16.7	23.3	14.1	93
(*b*) Digesters 12 and 10													
1958:													
June	10,100	12.9	6.7	75.2	43.1	32.4	330	250	23.3	14.4	21.0	12.5	95
July	11,100	11.7	7.2	73.3	51.5	37.7	400	290	24.6	15.0	23.5	13.7	94
Aug.	10,500	12.4	6.2	74.2	41.3	30.6	320	240	23.8	14.6	22.2	13.0	95
Sept.	11,200	11.6	6.6	75.0	47.5	35.6	370	270	24.1	15.5	21.9	13.4	94
Oct.	9,200	14.1	6.9	75.7	40.8	30.9	310	240	21.2	13.3	19.3	11.4	94
Nov.	9,300	14.0	6.7	79.1	39.7	31.4	310	240	20.7	13.5	18.9	11.3	92
Dec.	9,000	14.4	6.6	80.7	37.7	30.5	290	230	18.3	11.9	17.2	10.5	92
1959:													
Jan.	9,300	14.0	6.3	80.1	37.5	30.0	290	230	18.8	12.7	16.9	10.7	94
Feb.	9,200	14.1	7.2	78.1	42.1	32.8	320	250	20.4	13.7	17.8	11.4	94
Mar.	8,200	15.9	7.2	77.6	37.9	28.3	290	220	18.0	12.0	16.1	10.4	94
Apr.	7,900	16.5	6.5	75.8	33.0	25.0	250	190	15.2	9.6	14.4	8.7	95
May	8,100	16.0	6.6	77.4	34.4	26.6	260	200	16.9	10.7	15.1	9.1	96
June	6,100	21.3	7.8	73.9	30.5	22.6	230	170	14.0	8.8	12.2	7.3	93
July	5,700	22.8	7.2	75.7	26.3	19.9	200	150	14.0	8.8	12.6	7.4	91
Aug.	6,100	21.3	6.8	73.5	26.7	19.6	210	150	14.4	9.0	13.7	8.0	92
Sept.	6,600	19.7	7.4	73.2	31.4	23.0	240	180	16.5	10.4	15.0	8.7	90
Oct.	8,100	16.0	7.2	78.2	37.7	29.5	290	230	19.3	12.6	17.4	10.7	93
Avg	8,600	15.8	6.9	76.3	37.6	28.6	290	220	19.0	12.1	17.4	10.5	93

From the data in Table I, it can be seen that both digesters were equally loaded for about the first 4 mo. Sludge pumpage approximated 11,000 cu ft/day to each tank, resulting in a detention period of about 12 days in a tank having a nominal volume of 130,000 cu ft. The total solids loading aver-

aged 360 lb/day/1,000 cu ft, and for volatile solids it was 260 lb/day/1,000 cu ft.

Increased Loading of Digester No. 11

Digestion proceeded smoothly in both high-rate digesters, with no evidence of excessive loading for ten "turnovers" of tank content. Following this, Digester 11 started to receive an additional feeding. This increased the loading on No. 11 to 9/16 of the plant load, an increase of 1/8 over the previous period. But because of a decrease in over-all plant load, the solids and volatile loading rates remained almost the same as before. It was during this second period, in Nov., that mechanical difficulties prevented measurement of gas production from Digesters 11 and 9, and repairs could not be effected until Jan. This is why gas production data from Nov. 1958 to Jan. 1959 are missing.

Starting Feb. 2, the loading schedule was changed to feed 10/16 of the plant load to No. 11 and 6/16 to No. 12. After several days of heavy rain, the thickener pump suction lines clogged, resulting in large variations in the daily sludge pumping. On Feb. 6, this alternating glut and famine of sludge on top of the increased loading resulted in frothing of the seal of Digester 11. Volatile acids started increasing, reaching 1,200 mg/l by Feb. 9. Feeding of No. 11 was then reduced to ½ the plant load. By Feb. 16, normal functioning had been reestablished and the loading was restored to 9/16 of the plant load.

On Mar. 2, another trial of No. 11 at 10/16 of the plant load was begun. No difficulties were encountered during this 3-mo period of Mar. to May 1959. The loading rates to No. 11 increased about 1/10 over the previous period to 400 and 310 lb/day/1,000 cu ft of total solids and volatile matter, respectively; the detention period decreased to about 11 days.

In June, an attempt was made to increase the load to No. 11 to 11/16 of the plant total. The digester responded by frothing and by expanding the tank seal, without any significant increase in volatile acids. Further attempts to attain this higher loading were made in June, July, and Aug., but, again, frothing discouraged continuation. Finally, near the end of Aug., Digester 11 successfully accommodated 11/16 of the plant load and operated at this level without further difficulty until Nov. 19, 1959, when the plant had to be shut down to permit construction work for the plant expansion.

During Oct., this digester reached its highest level of loading, 490 and 380 lb/day/1,000 cu ft of total solids and volatile matter, respectively, at a detention period of 9.6 days, based on nominal digester volume. These rates were slightly exceeded in Nov. without evidence of overloading. During the entire period of the trial, the mixers succeeded in preventing any accumulation of scum.

Digester 12, at lower loadings, operated during the entire period without any difficulty. During the latter part of the run, the mixer speed was cut in half, eliminating most of the vibration of the digester cover. Even at this lower rate of mixing, no scum accumulated on the surface.

As for the other conditions of operation, the raw sludge contained 6.9 per cent total solids having a volatile content of 76 per cent. A maximum volatile content of 81 per cent was reached in the winter and the minimum of 73 in the summer. The high-rate digesters were maintained at a temperature averaging 93°F, ranging from a low of 90 to a high of 96.

The grease content of the raw sludge solids averaged 15.4 per cent on a dry basis, varying between 10 and 22 per cent. The sludge from the high-rate digesters averaged 11.1 per cent grease, indicating a 63-per cent destruction.

With the sludge solids leaving the system averaging 10.2 per cent grease, the over-all destruction was 69 per cent.

The amount of ash (that is, the total solids less the volatile matter) entering and leaving the high-rate digester can be calculated from the data in Table I. A loss of ash, exceeding 2,000 lb/day for both high-rate units is indicated. When the digesters were emptied at the end of the trial, about 15,000 cu ft of sand was found in each unit. Most of this material, had grain sizes less than 1/32 in. The loss of ash is thus accounted for. This loss of digester volume of about 12 per cent means that the actual loading rates at the end of the trial are about 12 per cent higher than indicated in the tables and the actual detention period about 12 per cent lower because both figures were calculated on the basis of the nominal volume of 130,000 cu ft.

Results

Of particular interest are the results of operation of Digester 11 which started at loading rates of 330 and 250 lb/day/1,000 cu ft of total solids and volatile matter, respectively, and attained rates of 490 and 380 lb/day/1,000 cu ft in Oct. 1959. Table II shows that digestion proceeded normally at an average pH of 7.3 and the volatile acids concentration (monthly averages) ranged from 150 in Sept. 1958 to 570 mg/l in Feb. 1959. This high value resulted from the intermittent pumping of raw sludge previously mentioned and was not typical of the other 16 months of operation. Volatile matter destruction averaged 56 per cent, dropping to 52 per cent for the last three months of highest loading. The digester and extractor together averaged 62 per cent destruction of volatile matter. Digesters 12 and 10, with an average total detention period of about 30 days, as against 22 days for No. 11 and 9, showed 58 per cent destruction of volatile matter for the high-rate unit and 63 per cent for the combined system. The per cent destruction of volatile matter was calculated from the difference in weight of volatile matter entering and leaving the digesters. The values shown in Table II appear to be normal.

Solids Concentration

The solids and volatile matter concentration of the digested sludges present some apparent anomalies. Digesters 11 and 12 produced sludges averaging about 3.3 per cent total solids, with about 60.5 per cent of it volatile matter. The solids concentration seems low for a sludge that was partially thickened prior to digestion. Moreover, the volatile content seems unduly high for what is presumably a well-digested sludge. However, if the large quantities of fine sand deposited in the high-rate digesters are considered and suitable corrections made, a somewhat different picture appears. The digested sludge solids concentrations in Digesters 9 and 10 then become about 3.7 per cent with a volatile content of 55 per cent. These are close to the values previously obtained with conventional stage-digestion.

Gas Production

Gas production was measured by means of rotary positive-displacement type gas meters, which are of high accuracy. However, vibration of the covers caused an undetermined quantity of gas to be lost from the high-rate digesters through the pressure relief valves. This condition was improved during the latter portion of the experiment by weighting the covers and stiffening the relief valve supports with guy wires. The gas production figures for Digesters 11 and 12 in Table III are, therefore, somewhat lower than the actual, especially for the first seven months of operation. This table also includes other data relative to gas production and gas quality.

The quantity of gas produced indicates normal digestion for both high-

TABLE II.—Analytical Data and Volatile Matter Destruction

Year and Month	Thickened Raw Sludge					H-R Digested Sludge					Volatile Matter Destruction			
											H-R Digester		Combined	
	TS (%)	VS (as % of TS)	pH	Vol. Acids (mg/l)	Alk. (mg/l)	TS (%)	VS (as % of TS)	pH	Vol. Acids (mg/l)	Alk. (mg/l)	(1,000 lb/day)	(%)	(1,000 lb/day)	(%)
(*a*) Digesters 11 and 9														
1958:														
June	3.7	61.8	7.3	240	4,600	3.3	58.9	7.6	80	5,400	18.5	57	20.8	64
July	3.5	61.1	7.3	160	4,200	3.3	59.2	7.4	60	4,700	22.6	60	23.8	63
Aug.	3.6	61.2	7.2	165	4,600	3.4	58.4	—	70	—	16.7	53	18.3	58
Sept.	3.3	64.9	7.3	150	4,200	3.1	61.6	7.3	130	4,600	20.2	57	22.0	62
Oct.	3.7	62.9	7.4	320	5,000	3.3	59.9	7.5	130	5,200	20.0	55	22.6	62
Nov.	3.5	65.7	7.3	340	4,800	3.3	61.1	7.4	420	4,900	21.1	57	23.2	63
Dec.	3.3	66.2	—	170	—	3.0	61.8	—	70	—	20.2	57	22.3	63
1959:														
Jan.	3.3	68.6	7.2	300	3,800	2.9	64.5	—	—	—	21.2	56	24.2	64
Feb.	3.6	67.5	7.4	570	5,550	3.2	63.3	7.4	80	6,400	21.2	56	24.5	64
Mar.	3.7	68.4	7.3	330	5,700	3.2	63.3	7.3	200	6,400	23.8	55	28.0	65
Apr.	3.4	63.3	7.2	420	6,000	3.0	62.7	7.4	320	6,400	23.8	60	25.9	65
May	3.4	64.0	7.4	290	4,900	3.1	60.0	7.3	450	5,500	20.6	56	23.1	63
June	4.2	63.3	7.4	350	4,800	3.6	60.4	7.5	190	5,700	22.7	56	25.8	64
July	4.0	62.2	7.4	190	4,100	3.8	58.7	7.5	140	5,000	19.5	55	21.4	60
Aug.	3.8	63.0	—	220	4,100	3.7	58.8	—	150	4,800	17.2	52	18.9	57
Sept.	4.2	63.6	—	—	—	3.7	58.2	—	—	—	19.6	51	23.3	60
Oct.	3.9	67.5	7.3	310	4,400	3.5	61.3	7.7	280	5,100	26.4	53	30.5	62
Avg	3.7	64.4	7.3	280	4,700	3.3	60.7	7.4	180	5,400	20.9	56	23.4	62
(*b*) Digesters 12 and 10														
1958:														
June	3.6	61.6	7.3	250	4,600	3.4	59.2	7.5	140	4,800	18.0	56	19.9	61
July	3.5	61.2	7.3	140	3,900	3.3	58.3	7.5	200	4,800	22.7	60	24.0	64
Aug.	3.6	61.3	7.2	165	4,350	3.3	58.5	—	—	—	16.0	52	17.6	58
Sept.	3.4	64.3	7.3	140	4,300	3.0	61.4	7.4	130	4,700	20.1	56	22.2	62
Oct.	3.6	62.5	7.4	190	5,000	3.3	59.3	7.6	140	5,600	17.6	57	19.5	63
Nov.	3.5	65.2	7.4	220	4,850	3.2	60.1	7.5	80	5,150	17.9	57	20.1	66
Dec.	3.2	65.2	—	155	—	3.0	60.9	—	50	—	18.6	61	20.0	66
1959:														
Jan.	3.2	67.5	7.3	110	4,000	2.9	63.7	—	—	—	17.3	58	19.3	64
Feb.	3.5	67.1	7.3	210	5,500	3.0	64.1	7.5	60	6,600	19.1	58	21.4	65
Mar.	3.5	66.6	7.3	290	6,000	3.1	63.3	7.4	140	6,400	16.3	58	17.9	63
Apr.	3.1	63.0	7.3	270	6,250	3.0	60.7	7.4	130	6,400	15.4	62	16.3	65
May	3.3	63.5	7.3	180	5,100	3.0	60.3	7.5	140	6,000	15.9	60	17.5	66
June	3.9	62.9	7.4	210	5,100	3.3	59.4	7.5	130	5,700	13.8	61	15.3	70
July	3.9	62.7	7.4	150	4,400	3.6	59.0	7.6	190	5,400	11.1	56	12.5	63
Aug.	3.7	62.4	—	200	4,200	3.5	58.3	—	130	4,700	10.6	54	11.6	59
Sept.	3.9	62.7	—	—	—	3.6	57.6	—	—	—	12.6	55	14.3	62
Oct.	3.7	65.3	7.4	660	4,600	3.4	61.5	7.6	310	5,100	16.9	57	18.8	64
Avg	3.5	63.8	7.3	220	4,800	3.2	60.3	7.5	140	5,500	16.5	58	18.1	63

rate units if allowances are made for the gas losses mentioned above. Gas produced measured 8.1 cu ft/lb of volatile matter added and 14.5 cu ft/lb of volatile matter destroyed for the more heavily loaded Digester 11, and 8.5 and 14.8 for No. 12. Gas production in No. 11 varied from about 2.0

cu ft/cu ft of digester volume to as high as 2.8 cu ft/cu ft for June and Oct., 1959, at the heavier loadings. For both high-rate units, the CO_2 content of the gas was close to 36 per cent.

TABLE III.—Gas Production

Year and Month	High-Rate Digester						Digestion Index (%/day)	Gas Produced in Extractor (1,000 cu ft/day)	Total Gas Produced		
	Gas Volume (1,000 cu ft/day)	Proportion of Total (%)	CO_2 Content (%)	Gas Produced					(1,000 cu ft/day)	(cu ft/lb vol. matter fed)	(cu ft/lb vol. matter destroyed)
				(cu ft/lb vol. matter fed)	(cu ft/lb vol. matter destroyed)	(cu ft/cu ft of dig. vol.)					
(*a*) Digesters 11 and 9											
1958:											
June	231.9	90	35.3	7.2	12.5	1.8	64	26.6	258.5	8.0	12.4
July	264.2	89	—	7.0	11.7	2.0	70	31.6	295.8	7.9	12.4
Aug.	258.6	89	35.2	8.1	15.5	2.0	65	32.2	290.8	9.1	15.9
Sept.	268.3	88	35.4	7.6	13.3	2.1	64	35.7	304.0	8.6	13.8
Oct.	277.1	88	36.7	7.6	13.9	2.1	62	37.9	315.0	8.7	13.9
Nov.	—	—	36.4	—	—	—	—	—	—	—	—
Dec.	—	—	35.2	—	—	—	—	—	—	—	—
1959:											
Jan.	—	—	35.5	—	—	—	—	—	—	—	—
Feb.	310.5	84	36.9	8.1	14.6	2.4	44	59.2	369.7	9.7	15.1
Mar.	346.7	86	36.1	8.0	14.6	2.7	56	58.1	404.8	9.3	14.5
Apr.	317.2	86	—	8.0	13.3	2.4	58	50.5	367.7	9.3	14.2
May	327.3	88	37.2	8.9	15.9	2.5	63	46.2	373.5	10.2	16.2
June	361.7	88	37.1	9.0	15.9	2.8	62	48.1	409.8	10.3	15.9
July	320.5	87	35.7	9.0	16.4	2.5	54	45.9	366.4	10.3	17.1
Aug.	296.6	86	35.5	9.0	17.2	2.3	51	46.3	342.9	10.4	18.1
Sept.	304.6	85	—	7.9	15.5	2.3	47	55.6	360.2	9.3	15.5
Oct.	367.0	83	35.5	7.4	13.9	2.8	52	73.4	440.4	8.9	14.4
Avg	303.7	87	36.0	8.1	14.5	2.3	58	46.2	350.0	9.3	15.0
(*b*) Digesters 12 and 10											
1958:											
June	241.7	89	34.9	7.5	13.4	1.9	64	29.2	270.9	8.4	13.6
July	256.7	88	32.5	6.8	11.3	2.0	63	34.7	291.4	7.7	12.1
Aug.	258.6	88	32.5	8.2	16.2	2.0	60	34.7	293.3	9.2	16.7
Sept.	265.0	88	34.9	7.5	13.2	2.0	63	36.3	301.3	8.5	13.6
Oct.	250.4	89	36.7	8.1	14.2	1.9	55	32.4	282.8	9.2	14.5
Nov.	257.3	88	37.9	8.2	14.4	2.0	52	35.2	292.5	9.3	14.6
Dec.	240.4	89	35.8	7.9	12.9	1.8	55	30.5	270.5	8.9	13.5
1959:											
Jan.	256.8	89	37.4	8.6	14.9	2.0	57	32.4	289.2	9.6	15.0
Feb.	281.3	87	38.4	8.6	14.7	2.2	49	40.7	322.0	9.8	15.0
Mar.	255.8	89	36.0	9.0	15.7	2.0	57	31.5	287.3	10.2	16.1
Apr.	243.1	90	—	9.7	15.8	1.9	58	25.6	268.7	10.7	16.5
May	245.6	90	36.9	9.2	15.5	1.9	56	27.2	272.8	10.3	15.6
June	221.8	90	36.4	9.8	16.1	1.7	44	23.9	245.7	10.9	16.1
July	192.1	89	35.6	9.7	17.3	1.5	36	23.5	215.6	10.8	17.2
Aug.	188.0	89	35.5	9.6	17.7	1.4	39	22.7	210.7	10.8	18.2
Sept.	170.6	88	—	7.4	13.5	1.3	39	22.4	193.0	8.4	13.5
Oct.	248.0	88	36.3	8.4	14.7	1.9	44	34.9	282.9	9.6	15.0
Avg	239.6	89	35.8	8.5	14.8	1.8	52	30.5	270.0	9.5	15.1

Table III shows the proportion of total gas that was produced in the high-rate units. At the beginning of the trial, the high-rate digesters produced about 89 per cent of the total gas measured. As loading increased on Digester 11 and the detention period decreased, a gradually decreasing proportion of the gas was produced until at the end, when the nominal detention was down to 9.6 days, the proportion had decreased to 83 per cent.

The gas production data for the high-rate units and gas extractors were used in calculating the digestion index. This index was developed by Torpey (1) as a measure of the velocity of digestion at a given digester loading. It is calculated from the expression:

$$\text{Digestion Index (\%/day)} = \frac{GQ}{gV} \times 100 \ldots (1)$$

in which Q is the daily sludge volume added, V is the nominal digester volume, G is the daily gas production from the high-rate digester, and g is the daily gas production of the gas extractor. The index measures the rate at which the potentially gasifiable material which accumulates in the high-rate digester is converted to gas.

For the first period of operation, with both digesters practically free of extraneous material, the digestion index averaged about 65 per cent per day. As the trial proceeded, the index decreased for both digesters. For Digester 11, which received an increasing load, the index became about 50; for No. 12, in which the load decreased, it dropped to 40 per cent per day.

The digestion index measures the efficiency of utilization of digester volume at a given loading, and the presence of any material which reduces the actual volume below the nominal will lower the index. In both high-rate units some 15,000 cu ft of fine sand had accumulated by the end of the trial, leaving about 88 per cent of the original volume. Based on the actual volume, Digester 11 during Oct. 1959, at a detention period of 8.5 days, operated at a digestion index of 59 per cent per day, still significantly lower than that at the beginning of operation.

Discussion of Loading Rates

During the trial, the high-rate digesters operated at an average total solids loading of 330 lb/day/1,000 cu ft and a volatile loading of 260 lb/day/1,000 cu ft of nominal digester volume. For five months, Digester 11 handled total solids loadings of from 400 to 490 lb/day/1,000 cu ft and volatile loadings of 330 lb/day/1,000 cu ft. These loadings appear to be the highest reported for long-term operation of actual plant digesters.

Since sludge sampling is notoriously inaccurate, how dependable are these loading rates? One way the accuracy may be judged is by making comparisons with the suspended solids capture based on analyses of raw sewage and final effluent (which method, of course, is subject to inaccuracies of its own). In general, the quantity of sludge produced as measured by the suspended solids capture method averaged about 87 per cent of the value calculated from sludge data, with some months in the latter part of the trial showing almost identical results. On this basis, the actual loading rates should be within one-eighth of those reported.

Loading rates also may be judged by the gas production relative to the volatile matter added. A normal value seems to be about 9 cu ft/lb of volatile matter added. The gas measured averaged 8.1 and 8.5 cu ft/lb for Digesters 11 and 12, respectively. Again, these figures are somewhat higher for the latter part of the trial. Agreement within 10 per cent of the expected value is thus indicated. This is about as close an agreement as can be expected under plant conditions.

In view of the uncertainties of sludge sampling and the error in loading rates

that would be introduced thereby, the best measure of digester performance might be gas production per unit of digester volume. For the last 9 mo of operation, Digester 11 produced gas at the rate of 2.5 cu ft/cu ft of nominal digester volume, and 2.8 cu ft/cu ft for the months of June and Oct. 1959. Based on a digester volume reduced 12 per cent by sand accumulation, gas production in Oct. averaged 3.2 cu ft/cu ft of actual digester volume.

Loading Rates for Design

This trial did not reach the limit of loading. At the close, volatile solids loading rates of about 400 lb/day/1,000 cu ft were being handled without difficulty. During the months of June and July, however, efforts to increase the loading rate above 300 lb/day/1,000 cu ft resulted in instability in the form of froth inside the digester and liquefaction and rising of the digester seal.

The reasons for this behavior are obscure, inasmuch as the digester accommodated significantly higher loading rates for several months. Since it did happen, some caution is necessary in choosing a design loading rate. A design figure for volatile solids loading of 250 lb/day/1,000 cu ft was chosen on the basis of the ease and stability of operation at this level and the margin of safety it gives.

This design figure applies specifically to the Jamaica plant where industrial wastes are not a problem. At the expanded Bowery Bay plant which now receives substantial quantities of toxic wastes including copper, chromium, nickel, and cyanides, the digesters were at times unable to function at all, and when they did operate, at loading rates only a fraction of those used at Jamaica. Accordingly, it becomes imperative to ban toxic wastes from the sewers or reduce them to tolerable concentrations if any form of digestion is to be employed.

Besides the selection of a solids loading rate, there is the question of how low a detention period the digester can tolerate. Figure 2 shows the relationship between gas produced and detention period as corrected for loss of volume due to accumulation of sand. Above 12 days of detention, the curve becomes almost horizontal, indicating no benefit from a greater detention. Below 12 days, the curve begins to drop off, and at an increasing rate. At the sludge concentration of this trial (6.9 per cent total solids, 76 per cent volatile matter), a volatile solids loading of 250 lb/day/1,000 cu ft results in a detention period of 13.5 days, so that the detention period is not a factor at the design loading rate. It might assume importance at higher loading rates or even at this loading rate with less concentrated sludges.

Digestion Index and Tank Utilization

During the first four months of the trial, while both digesters were being fed equally and were relatively free of sand accumulation, the digestion index averaged about 65 per cent per day. Unpublished work by Torpey on the digestion of thickened combined primary and modified aeration sludge in a pilot digestion tank indicates a digestion index of about 95 per cent per day. This work of Torpey's was performed on sludge somewhat similar in character and solids content to the Jamaica sludge.

Since the digestion index measures the efficiency of tank utilization, the test data indicate that the Jamaica tank volume is about 70 per cent utilized as compared with a completely efficient pilot digester. The reasons for the decrease in digestion index for Digester 11 as the trial proceeded are not apparent. The possibility exists that as digester contents were transferred, there was some short-circuiting of partially digested material to the gas extractors. This would violate the assumption implicit in the definition of the digestion index that the material

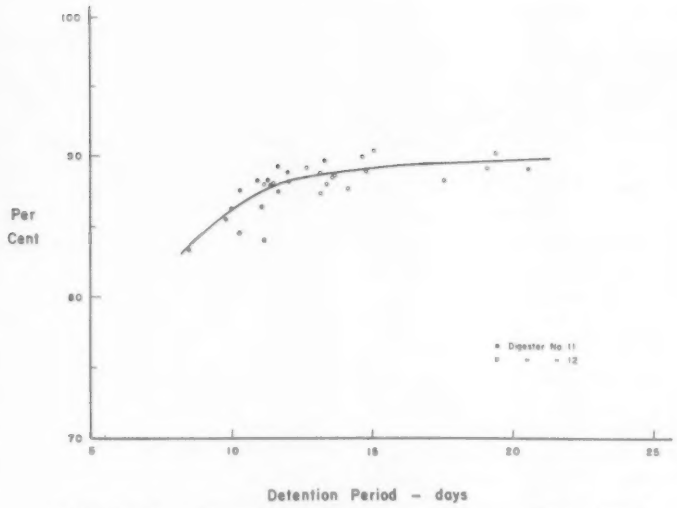

FIGURE 2.—Proportion of total gas produced during various detention periods.

displaced to the gas extractor is perfectly representative of the contents of the high-rate unit. Short-circuiting is an item to be considered in planning feed and withdrawal lines of a high-rate digester.

Structures and Equipment

Proper provisions for high-rate digestion start with some means of feeding concentrated sludge. Since no supernatant liquid is released in either the high-rate digester or gas extractor, excess water must be removed from the sludge prior to digestion. At Jamaica, the thickeners are being modified by the addition of a heavy-duty picket-fence thickening mechanism. To pump the heavy sludge produced, plunger-type pumps will be placed under the thickeners to eliminate long suction lines. They will discharge into a 12-in. line carrying a continuous flow of active digester contents, thus diluting the thickened sludge, maintaining low pump discharge pressures, and keeping the line free from grease deposits.

In the high-rate digester, a means of completely mixing the tank contents is required if the unit is to be utilized efficiently. At Jamaica, the propeller-type draft-tube mixers operated effectively, prevented any scum accumulation whatsoever, and ran for over 1½ years without serious mechanical breakdown. However, for this type of mixer to operate properly, the liquid level of the tank must be maintained within 3 in. of optimum. Also, the liquid level must be kept from flooding the lower shaft bearing.

Some method of heating the digester must be provided, such as an external heat exchanger through which digester liquid is pumped and heated. The heated liquor should return to the digester via the raw sludge feed line, thereby diluting and seeding the raw sludge and aiding in its mixing with the tank contents.

The transfer piping (with an adjustable overflow for setting the tank liquid level when using mechanical mixers) should be short and direct. It should be arranged to prevent trapping of gas and interruption of flow. Its intake should be above the bottom of the tank so that heavy material or sludge will not enter the line and clog

it. Separate withdrawal lines should be provided, with suitable pumps to either recirculate or remove heavy material from the bottom.

It is desirable, for efficient tank utilization, to have as few structures, supports, piping, etc. as possible. The digester should be equipped with suitable gas meters to measure gas production, the best indicator of digester performance. Portholes in the roof are desirable. Through them, mixer performance, frothing, and scum accumulation can be observed.

The items mentioned above are already being used in the design of new or expanded New York City plants. At Newtown Creek, a digester capacity of 3 cu ft/cap formerly would have been considered as a basis of design. For the 2,500,000 people in the area, this would have required some 7,500,000 cu ft of tank volume. Instead, the plans propose 1,270,000 cu ft, and the capital savings in tank capacity alone is over $6 million.

At Jamaica itself, construction has started on changes which will result in an increase of plant design capacity from the present 65 mgd to 100 mgd. The plant will be capable of using either the step aeration or modified aeration processes. Under former design criteria, this would have required four more digesters at a cost of $600,000. Now, Digesters 7 and 8 will be converted to high-rate units and Digesters 1 through 6 will become storage units, to be used to protect the plant against extended interruptions to sludge removal that could occur in the winter due to freezing of Jamaica Bay.

Summary

This paper describes the operation of high-rate digesters at the Jamaica Pollution Control Project. It covers a period of one and one-half years. The digesters operated in a satisfactory manner at volatile solids loadings ranging from 150 to 380 lb/day/1,000 cu ft of digester volume. A design loading of 250 lb/day/1,000 cu ft was selected as suitable for digestion of thickened modified aeration sludge similar to Jamaica sludge. Starting at a loading equivalent of 0.5 cu ft of digester capacity per capita, one high-rate digester accommodated 11/16 of the plant load, equivalent to 0.34 cu ft of capacity per capita. The selected loading rate represents a design capacity allowance of 0.5 cu ft/cap.

The results of digestion were satisfactory for 18 months of operation. The pH averaged 7.3, volatile acids were normally well below 500 mg/l, and the CO_2 content of the gas averaged 36 per cent. Volatile matter destruction averaged 57 per cent. Daily gas production started at 2.0 cu ft/cu ft of digester volume and was about 3 cu ft/cu ft at the highest loading rate.

Acknowledgments

Thanks are extended to George W. Winslow, Superintendent in charge of the Jamaica Pollution Control Project, and his operating staff for their continuous cooperation in the operation of these digestion tanks. The authors wish also to express appreciation for the advice and aid of Wilbur N. Torpey, Chief, Bureau of Sewage Disposal Operation, and to Martin Lang, Assistant Chief, for his aid in presenting the data.

The authors are especially grateful to Commissioner Frederick H. Zurmuhlen and to William A. O'Leary, Director, Division of Sewage Disposal, whose deep interest in improved techniques made these tests possible.

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OPERATOR TRAINING AT THE ERIE SEWAGE TREATMENT PLANT *

By Paul Cygan

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Prior to 1953 the Erie sewage treatment plant was of the primary type. It consisted of a grit chamber, screenings house, screenings and grease incinerator, primary tanks, digesters, and sludge drying beds. Beginning in 1953, the construction of secondary treatment facilities was started. In October, 1956, the new activated sludge plant went into operation. This plant is designed to treat an average flow of 45.0 mgd from a contributing population of 200,000. The present sewage flow is about 35 mgd and the contributing population is about 165,000. At the present time the plant operates as a conventional activated sludge plant, but when the flow reaches the design capacity it can be operated on the modified-aeration principle.

Before the new plant was put into operation the operators, of course, had experience in only primary treatment. Therefore, all operators, including the old and new men, had to be trained in the operation of activated sludge units. Consequently, some type of training program had to be instituted.

This program that was developed consisted mainly of on-the-job training as outlined below:

1. Meetings and classes for all personnel.
   (a) At these meetings the operation and functions of the many different treatment units and equipment were discussed with the operators. The operation, maintenance, and service procedures for the equipment were explained.
   (b) Tours were made through the plant at which time the operating procedures and duties were explained.
   (c) Question and answer periods were held. These meetings were an excellent aid to operator training.
   (d) Attendance at section meetings of the Pennsylvania Sewage and Industrial Wastes Association. An attempt was made to send as many operators as possible to these meetings where the operation and problems of different types of sewage treatment plants are discussed. In addition, other plants are visited and sometimes problems encountered at these plants are similar to problems at Erie.
2. Special training for shift operators. There are five shift operators at Erie, four of whom work on regular shifts and the fifth is used for relief work. During the training program for shift operators, all five had an opportunity to do relief work or work on the day shift. When the operator worked on day shifts only the training program consisted of the following items:
   (a) Working with the maintenance crew for a period of time. This gave the operator an opportunity to learn to service, operate, and maintain some of the different treatment units and equipment.

* Presented at the 31st Annual Conference, Pennsylvania Sewage and Industrial Wastes Assn.; University Park, Pa.; Aug. 12–14, 1959.

The operator actually helped to do some repair work.

(b) Working in the laboratory with the plant chemist. Here the operators were taught how to run tests and make out operating reports. This is invaluable training for the operators and in the future operators will probably spend more time in the laboratory.

(c) Sewage operators correspondence course. Some operators are now taking the ICS course for sewage plant operators and results so far indicate that this course is a valuable training aid. The course includes instruction on arithmetic calculations, laboratory operation, and maintenance.

Future training for the operators will consist of:

1. More laboratory training.
2. Classroom sessions in which laboratory tests and data will be discussed and problems will be worked out. More emphasis will be put on sewage plant arithmetic and problem calculations.
3. More discussions and explanations on operation and maintenance of equipment.
4. Attendance at the Annual Conference of P S I W A. At least one shift operator or the chemist and the superintendent will attend these meetings.
5. Attendance at operators' short courses.

EFFECTS OF INFILTRATION *

By David P. Backmeyer

Superintendent, Sewage Treatment Plant, Miami, Fla.

Infiltration and storm water inflow problems in south Florida may be similar in many respects to those of other Southern coastal cities. Fresh water and salt water can cause trouble and some cities are plagued by both.

Because of the flatness of the land, many Florida sewage collection systems contain an unusually high number of pumping stations. There may be from 15 to 20 in small cities and from 50 to 75 in larger ones. Consequently, unauthorized water in the sewers, whether fresh or salt, creates a costly sewage collection problem.

Examples

A West coast city of 25,000 normally treats a dry weather flow of 2.5 mgd. Some of the sewers are 40 to 50 years old, and they take in large quantities of fresh water during and after a hard rain. Flows at the plant jump to 7.5 mgd, and the sewage is loaded with sand. In less than a year's time the sludge digester was half full of sand. The raw sludge pumped during these periods contains 20 per cent solids which have a volatile content of only 10 to 12 per cent. Repairs to the sewer lines appear to be economically unsound. New sewers will have to be installed in some areas.

Another city reports the infiltration of both fresh and salt water. This particular city has 35 small pumping stations which discharge to two large stations, the latter pumping to the treatment plant. During severe rainstorms, flow rates at the treatment plant may rise from 35 to 100 mgd within 30 min. Numerous storm water

* Presented at the Operators' Forum of the 32nd Annual Meeting of the Federation of Sewage and Industrial Wastes Assns.; Dallas, Tex.; Oct. 12–15, 1959.

connections to the sanitary system, which in some areas provide the only means of drainage of surface water, contribute additional large quantities to the interceptor system. During the rainy season, when the ground water table is high, some of the older sewers take in large volumes of ground water, and the sewage flows at the treatment plant continue to be from 60 to 100 per cent above normal for many days after a heavy storm period ends.

In reply to a written inquiry mailed to 10 Florida cities located in the southern part of the state, 8 reported plant capacities were greatly exceeded during rainy periods. In most of these places, efforts are being made to repair the sewers if the lines are not too old. A closed-circuit television camera, designed especially for sewer inspection work, has been found to be an excellent way of locating leaks. Various types of quick-setting cements, applied by jet application around the outside of the pipe near the leak, have been effective in repair work.

Miami Experience

In addition to the added costs of pumping excess water and the obvious evils of hydraulic overload on the treatment plants, salt water infiltration may cause other plant operational problems. In Miami, some of the sewers are located close to Biscayne Bay, and infiltration in these lines generally carries a high concentration of the dissolved salts normally found in sea water. As a result, the raw sewage may contain from 3,000 to 4,000 mg/l total solids. The chlorides in this sewage will range from 800 to 2,000 mg/l. After treatment by the high-rate activated sludge process, effluent is reprocessed in a water treatment plant, and it is used as a general service water throughout the plant. Waters containing high amounts of dissolved salts greatly accelerate corrosion of structural and equipment metals with which it comes in contact, and protection of these metals in Miami has created a complex and expensive maintenance problem. Bucket elevators, bar screens, sludge concentrators, grit collectors, and pumps are but a few of the machines seriously affected.

Before the treated effluent can be used to sprinkle the plant lawn and shrubs, it must be diluted with city water. This represents an added monthly cost of several hundred dollars during the drier winter season when the lawn must be watered regularly.

Ocean water contains approximately one-seventh as much sulfate as chloride. Salt water infiltration, therefore, provides an abundant source of sulfur which may be converted to hydrogen sulfide by bacterial action in sewers and in sludge digestion systems. The Miami sludge digesters produce from 200,000 to 300,000 cu ft/day of sewage gas, but it is highly contaminated with hydrogen sulfide. Before the gas can be used as an engine fuel, it must be scrubbed for removal of this unwanted compound. A wet-type gas scrubber, which utilizes plant effluent, has been developed and is in use for this purpose.

TIPS AND QUIPS

Oil-Leak Stopper

At Cincinnati, it has been found that Teflon tape, in ½-in. rolls, can be used to stop fuel and lubricating oil leaks. The tape is simply wrapped around the threads.

More than one cigar at a time is excessive smoking.

MARK TWAIN

Side Lights on Sewer Construction

At Boise, Idaho, sewers are being extended to serve the Bench district. Over and above the construction events, these side lights have been recorded:

1. Weekly reports on the progress and schedule of work are sent to official agencies and are published in the newspaper to guide the traffic flow.

2. Public relations men, employed by the contractor, check complaints and advise those in the immediate area of work how to make the inconvenience as slight as possible.

3. Telephone, gas, water, pipeline, and power companies have representatives on the project site to take over in emergencies.

4. City and county engineers select weekly those streets that are to be entirely rebuilt and those that are to be patched only. If the contractor does not restore the street, the dollars which would have been spent are turned over to the city or county for their street rebuilding funds.

5. For house connections, all construction data are recorded on special forms. In this way, a complete record will be available for all property owners.

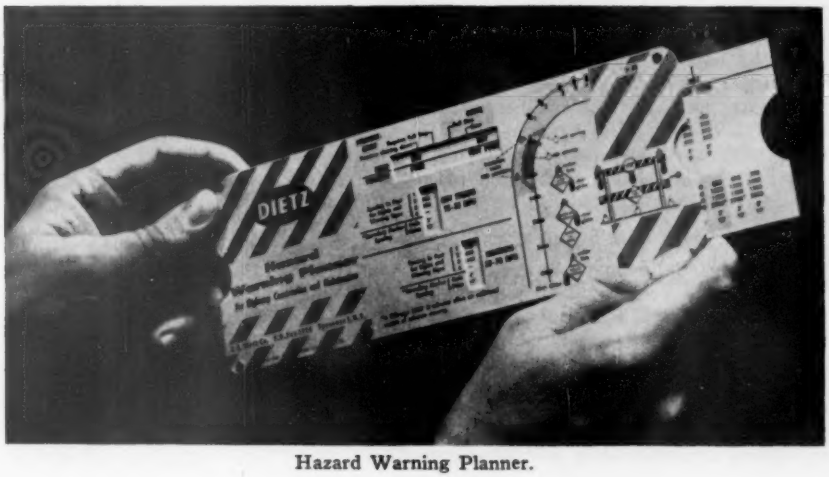
Highway Hazard Warning Planner

A hazard warning planner takes the guesswork out of the job of providing adequate roadside warning devices (see below).

By sliding the inner card through the outer card, you see at a glance practically every factor governing the placement of signs, flagmen, traffic cones, barricades, lanterns, torches, and flashers.

Diagram at right illustrates a typical work area along a curved section of either urban or rural road. At left are three boxes: box at top denotes road and visibility conditions on the straightaway and on the curve of the roadway; middle box shows the spacing of the signs, lights, and boundary markers for city streets; and bottom box reveals the same information for rural work sites. Back of planner lists directions, plus desirable characteristics of and maintenance tips for warning devices.

Request Hazard Warning Planner, Department RB, R. E. Dietz Company, Post Office Box 1214, Syracuse 1, N. Y.



Hazard Warning Planner.

Editorial

PUBLIC RELATIONS AND YOUR FEDERATION

The term "Public Relations" demands a definition because of a very wide use or perhaps misuse of the term. In the wastewater utility field, the first element of public relations is sound drainage service for the community served. After this, the public's attention can be drawn to the utility by conduct of its employees and utility operation with respect to the utility user. This means provision and maintenance of service with a maximum consideration for convenience of the user.

At its final meeting in October 1959, at Dallas, Texas, the Board of Control authorized a firm advance by the Federation in public relations activities. For the first time, a specific sum was approved in the 1960 calendar year budget for this activity. A further condition of the budget was to eliminate, if at all possible, deficit financing which had been necessary for two previous calendar years. This is certainly in keeping with the best financial policy.

The Public Relations Committee, under the chairmanship of Mr. A. C. Bryan of Houston, Texas, recommended that the Board make this move. It is the hope of the Public Relations Committee that the operation of the first year could initiate additional activities in this direction, and provide a solid program for future endeavors. The Board of Control sanctioned this attack and provided funds to its maximum ability.

The Board's authorization is accepted as a challenge to start this activity for the benefit of all those associated with the Federation.

The beginning of such an activity as recognized by the budget is acceleration of past production rather than embarking on an entirely new activity. For example, prior to the 1959 meeting in Dallas, approximately 100 news releases prepared by the Federation Staff were available for distribution as appropriate at the meeting. These releases, augmented by those prepared by the Publicity Staff assembled at the meeting, gave the Dallas meeting the best news coverage which any Federation meeting has enjoyed. In addition, both television and radio were used. To the Dallas "News Corps" go credit and Federation appreciation for this service. The added appropriations will help achieve the higher goal for future meetings as set by this production. This production set a higher goal for future meetings which the added appropriations will help achieve. It is fully realized that such publicity is only a small part of a full public relations program.

Another step is the increased use of what is already available. On the following two pages of this issue you will find a list of prepared material to assist public relations programs. Get it and let it work for you.

For several years, the American Water Works Association and the Water and Sewage Works Manufacturers' Association have been engaged in public relations programs. The expenditures of these organizations make the Federation outlay for the similar purpose seem like a pittance, but the joining of the Federation with direct expenditures in the effort will bring returns much beyond the relatively small expenditure. The experience of these organizations will clearly indicate the direction of Federation effort for the maximum return. Even though the Federation is not joining with these organizations on the basis of equal financial participation, there is the fullest spirit of cooperation and enthusiasm for progress on this front.

R.E.F.

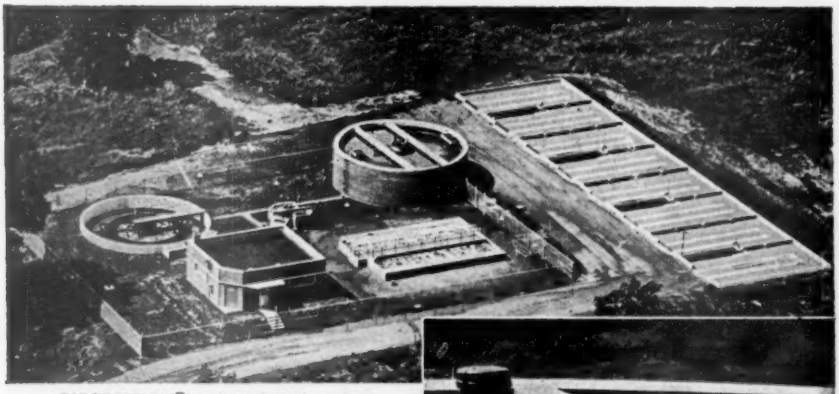
PUBLIC RELATIONS MATERIALS

Most of this list was compiled by the Public Relations Committee of the Water Pollution Control Federation. Knowing that there must be other worthwhile items not included, the Federation invites anyone to draw attention to missing items for consideration as additions to the list. Please send at least one copy of each item to the Federation office.

PUBLICATION	SOURCE	AVAILABILITY
Operator Advancement Packet *Public Relations Packet*	**Water Pollution Control Federation, 4435 Wisconsin Avenue, Washington 16, D. C.**	Limited quantity at 50¢
Our Growing Water Problems *Protecting Our Living Waters* *Building for Clean Waters*	**National Wildlife Federation, 1412 16th Street, N.W., Washington 6, D. C.**	Limited quantity at no cost
Concepts of Conservation	**The Conservation Foundation, 30 East 40th Street, New York 16, N. Y.**	Limited quantity at no cost
The Water and Sewage Industry Today and Tomorrow	**The Water and Sewage Works Manufacturers Association, Inc., 165 Broadway, New York 6, N. Y.**	Limited quantity at no cost
Washing Our Water: Your Job and Mine	**Public Affairs Pamphlets, 22 East 38th Street, New York 16, N. Y.**	Single copy 25¢ Quantity rates available
Sewers and Civilization *Sewage Treatment Works* *Vote "Yes" for Sewers* *Financing Water and Sewage Works* *Untreated Sewage—A Community Menace*	**Portland Cement Association, 33 W. Grand Avenue, Chicago 10, Ill.**	Available in the United States and Canada only, at no cost
The Wrong Enemy (Outdoor America Magazine Article)	**The Izaak Walton League of America, 1326 Waukegan Road, Glenview, Ill.**	Limited quantity at no cost

PUBLICATION	SOURCE	AVAILABILITY
The Worst Public-Works Problem (Fortune Magazine Article)	The Water and Sewage Works Manufacturers Association, Inc., 165 Broadway, New York 6, N. Y.	Limited quantity at no cost
Idea Packet	Clay Products Association, P. O. Box 172, Barrington, Ill.	Limited quantity at no cost
A Water Use Policy *Pollution Abatement in the Pacific Northwest*	Outdoor Writers Association of America, Inc., 7 St. Paul Street, Baltimore 2, Md.	Limited quantity at no cost
Pollution Control	Mississippi Valley Association, 1978 Railway Exchange Building, St. Louis 1, Mo.	Limited quantity at no cost
Let's Clean Up All Our Poisoned Rivers (The Reader's Digest Article)	The Reader's Digest, Pleasantville, N. Y.	Reprints available in quantity lots at reasonable prices
Everyone Can't Live Upstream *Clean Water and How to Get It*	General Electric Company, 1 River Road, Schenectady 5, N. Y.	$100.00 per 100 30¢ each
The Living Waters	Department of Health, Education and Welfare, Public Health Service, Division of Water Supply and Pollution Control, Washington 25, D. C.	15¢ each*
Water Pollution in the United States		No cost*
The Water Pollution Control Program of the U. S. Public Health Service		25¢ each*
Facts About the Federal Water Pollution Control Act of 1956		20¢ each*
Meeting Community Sewage Treatment Needs Under the Construction Grants Program		No cost*
Statistical Summary of Sewage Works in the United States		15¢ each*
Municipal Sewage Treatment Needs		15¢ each*
The Fight to Save America's Waters (Mark Trail)		No cost*
On the Water Front	League of Women Voters of the United States, 1026 Seventeenth Street, N.W., Washington 6, D. C.	25¢ each
The National Voter		10¢ each
Know Your River Basin		25¢ each

* Single copies available from Department of Health, Education and Welfare, Public Health Service, Division of Water Supply and Pollution Control, Washington 25, D. C. Quantity orders available from the Superintendent of Documents, Government Printing Office, Washington 25, D. C.



BIOSORPTION® Activated Sludge Plant
Neillsville, Wisconsin

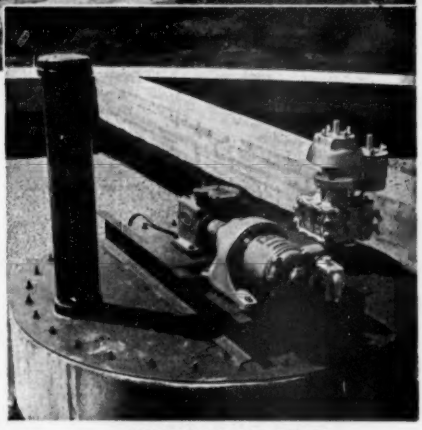
Consulting Engineers
Davy Engineering Co., Inc
La Crosse, Wisconsin

4 SUPERIOR FEATURES

"Varec"

PRESSURE RELIEF and VACUUM BREAKER VALVE with FLAME ARRESTER

FIG. No. 5800C



"VAREC" Fig. No. 5800C
Pressure Relief and Vacuum Breaker Valve installed on INFILCO unit.

1. The multi-plate Flame Arrester bank has larger area than competitive units of same size.

2. Much more flow per minute than same size competitive equipment, due to less capillarity and friction in the Flame Arrester passageways; streamlining and expanding passageways of Pressure Relief and Vacuum Breaker Valve.

3. Easy to clean. Just loosen frame holding Flame Arrester plates together — plates separate to permit easy cleaning with distillate, chemical solution or wire brush.

4. All aluminum construction makes "VAREC" Pressure Relief and Vacuum Breaker Valve corrosion resistant. Lighter weight facilitates installation.

The flame arresting element is identical to that listed by Underwriter's Laboratories and approved by Associated Factory Mutuals Laboratories for use on oil storage tanks on which hazard is considerably greater than that generally encountered in sewage treatment plants.

Send for "VAREC" Catalog S-3 today.

"Varec"

THE VAPOR RECOVERY SYSTEMS COMPANY

2820 North Alameda Street, Compton, California
Cable Address: Varec Compton California (U.S.A.) All Codes

S-15

Available from Authorized Equipment Agents throughout the U.S. and Canada.

NEW MANUAL AVAILABLE

M. O. P. #9 — SEWER DESIGN AND CONSTRUCTION

Several years of joint effort between the Water Pollution Control Federation and the Sanitary Engineering Division of the American Society of Civil Engineers have produced a major addition to the "Manuals of Practice" series. "Design and Construction of Sanitary and Storm Sewers" has been designated M. O. P. #9.

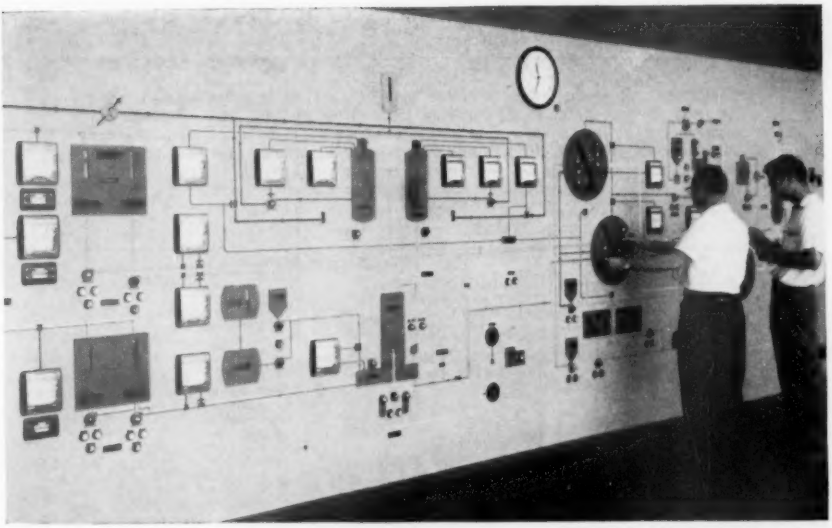
This illustrated, 12-chapter manual of 283 pages includes detailed coverage of project planning, investigations, hydraulics, design, construction materials and methods, specifications, structural requirements of storm and sanitary sewers, and pumping stations.

A convenient order form for this and other publications appears elsewhere in this issue. The manual is $7 per copy postpaid if remittance is with order. Federation members may purchase the manual for $3.50.

WATER POLLUTION CONTROL FEDERATION

4435 Wisconsin Avenue **Washington 16, D.C.**

at **BOEING** Airplane Company...



Central Graphic Control Panel for Boeing's Industrial Waste Treatment Plant. Panel includes controllers for flow and liquid level of various tanks, as well as recorder-controllers for the Foxboro ORP meters. Consulting Engineers: *Wilson & Company, Salina, Kansas.*

Foxboro continuous control system

"TAMES" TOXIC WASTE

At the Boeing plant in Wichita, Kansas, toxic hexavalent chromate waste from plating tanks must be reduced to trivalent chromium. Control of this complicated reduction process is handled by a Foxboro Continuous Waste Control System.

Four Foxboro ORP (oxidation-reduction potential) Meters are the heart of the system. These sensitive instruments take continuous ORP electronic measurements — control addition of sulphur dioxide when oxidation potential starts to rise.

Simple or complex — waste treatment systems are everyday business for Foxboro. Years of experience, plus pace-setting instruments like the Foxboro Magnetic Flow Meter, the Foxboro Dynalog* Recorder and the Foxboro ORP Recorder have made it possible.

Write us about your industrial waste treatment problem. We'll be glad to send you literature — or have an engineer call on you at your convenience. **The Foxboro Company, 885 Neponset Ave., Foxboro, Mass.**

*Reg. U. S. Pat. Off.

FOXBORO

REG. U.S. PAT. OFF.

WASTE CONTROL SYSTEMS

WATER POLLUTION CONTROL PRODUCT GUIDE

This list of products and services is offered as an information aid. The list was derived by solicitation from those firms listed. The JOURNAL will make every effort to keep this list current with the help of members and advertisers. All Associate Members and all advertisers for the past calendar year are included. Many of the services and products are advertised in this issue. For an alphabetical listing see Index to Advertisers in back of JOURNAL.

Aerators (*also see* Diffusers, Air)
Alpha Ltd. (Switzerland)
American Well Works
Chicago Pump Co.
Dorr-Oliver Inc.
Eimco Corp.
Graver Water Conditioning Co.
Infilco Inc.
Link-Belt Co.
Pacific Flush Tank Co.
Penberthy Mfg. Co., Div. of Buffalo-Eclipse Corp.
Permutit Co., Div. of Pfaudler-Permutit Inc.
Smith & Loveless, Inc.
Walker Process Equipment Inc.
Wemco Div., Western Machinery Co.
Yeomans Brothers Co.
Zimmer & Francescon

Agitators
Link-Belt Co.

Air Cleaning Equipment
Westinghouse Electric Corp.

Air Compressors (*also see* Blowers, Compressors, and Fans)
Chicago Pump Co.
Fairbanks, Morse & Co.
Komline-Sanderson Engr. Corp.
Worthington Corp.
Yeomans Brothers Co.

Air Diffusers (*see* Diffusers, Air)

Asbestos Cement Pipe Products
Filtration Equipment Corp.
Industrial Materials Co.
Johns-Manville Sales Corp.
Keasbey & Mattison Co.

Ash Handling Equipment
Link-Belt Co.

Automobiles and Trucks
Vulcan Materials Co.

Bearings
Link-Belt Co.

Bins, Storage (*see* Tanks)

Biologists (*see* Directory of Engineers)

Blowers (*also see* Air Compressors, Compressors, and Fans)
Chicago Pump Co.
Roots-Connersville Blower, Div. of Dresser Industries Inc.
Sutorbilt Corp.
Yeomans Brothers Co.
Zimmer & Francescon

Boilers
Combustion Engineering, Inc.

Building Maintenance Equipment and Supplies
Homestead Valve Mfg. Co.

Cast Iron Pipe Products
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
Industrial Materials Co.
U. S. Pipe & Foundry Co.
R. D. Wood Co.

Cement (*see* Concrete)

Centrifuging Equipment
Bird Machine Co.

Chains
Chain Belt Co.
Link-Belt Co.
Webster Mfg., Inc.

Chemical Feed Equipment
Builders-Providence Div., B-I-F Industries
Eimco Corp.
Fischer & Porter Co.
Graver Water Conditioning Co.
Infilco Inc.
Jeffrey Mfg. Co.
Komline-Sanderson Engr. Corp.
Link-Belt Co.
Omega Div., B-I-F Industries
Permutit Co., Div. of Pfaudler-Permutit Inc.
Proportioneers Div., B-I-F Industries
Wallace & Tiernan Inc.

Chemicals
Cloroben Chemical Corp.
Dow Chemical Co.
Fisher Scientific Co.
General Chemical Div., Allied Chemical Corp.
Glenn Chemical Co.
Tennessee Corp.
Vulcan Materials Co.

Chemists (*see* Directory of Engineers)

Chlorination Equipment
Builders-Providence Div., B-I-F Industries
Everson Mfg. Co.
Fischer & Porter Co.
Graver Water Conditioning Co.
Wallace & Tiernan Inc.
Zimmer & Francescon

Clarifier Equipment (*also see* Sedimentation Equipment)
Alpha Ltd. (Switzerland)
American Well Works
Ralph B. Carter Co.
Chain Belt Co.
Chicago Pump Co.
Dorr-Oliver Inc.
Eimco Corp.
Graver Water Conditioning Co.
Hardinge Co., Inc.
Infilco Inc.
Jeffrey Mfg. Co.
Komline-Sanderson Engr. Corp.
Lakeside Engineering Corp.
Link-Belt Co.
Permutit Co., Div. of Pfaudler-Permutit Co.
Walker Process Equipment Inc.
Yeomans Brothers Co.
Zimmer & Francescon

Clay Pipe Products
Industrial Materials Co.
National Clay Pipe Mfrs., Inc.
Wedge-Lock Clay Pipe Mfrs., Inc.

Coatings and Linings (Pipe and Tank)
Amercoat Corp.
Centriline Corp.
Inertol Co., Inc.
Koppers Co., Inc.
National Water Main Cleaning Co.
Perry-Austen Mfg. Co.
Pittsburgh Coke & Chemical Co.
Stebbins Engr. & Mfg. Co.
Vulcan Materials Co.

Comminutors (*also see* Shredders and Grinders)
Alpha Ltd. (Switzerland)
American Well Works
Chicago Pump Co.
Dorr-Oliver Inc.
Gruendler Crusher & Pulverizer Co.
Infilco Inc.
Jeffrey Mfg. Co.
Smith & Loveless, Inc.
Walker Process Equipment Inc.
Worthington Corp.

Compressors
Chicago Pump Co.
Fairbanks, Morse & Co.
Komline-Sanderson Engr. Corp.
Roots-Connersville Blower, Div. of Dresser Industries Inc.
Worthington Corp.
Yeomans Brothers Co.

Computers
Minneapolis-Honeywell Regulator Co., Brown Instruments Div.

Concentrators (*see* Sludge Concentrators)

Concrete
Portland Cement Assn.
Vulcan Materials Co.

Concrete Pipe Products
American Concrete Pressure Pipe Assn.
American-Marietta Co.
Gray Concrete Pipe Co., Inc.
Industrial Materials Co.
Lock Joint Pipe Co.
Portland Cement Assn.
Price Bros. Co.
Vulcan Materials Co.

Construction Equipment
Chain Belt Co.
Eimco Corp.
Worthington Corp.

Controls (*also see* Instruments, Recording and Control)
Bailey Meter Co.

Proceedings of Member Associations

WEST VIRGINIA SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 13th Annual Meeting of the West Virginia Sewage and Industrial Wastes Association was held jointly with the 21st Annual Meeting of the West Virginia Section of the American Water Works Association at the Chancellor Hotel, Parkersburg, W. Va., on Oct. 28–30, 1959.

Total registration was 223 including 28 ladies.

The program committee was headed by Bern Wright, and among the very fine papers presented were these:

"America Will Grow 'Up'—As It Grows 'Down'," by Morris M. Cohn, Editor, *Wastes Engineering*, New York, N. Y.

"The Role of Water in West Virginia's Social and Economic Growth," by Walter Gumbel, Conservationist, Monongahela Power Company, Fairmont, W. Va.

"Sewage Sludge Disposal by Wet Air Oxidation Process," by F. J. Zimmerman, Rothschild, Wis.

"Operation of the Parkersburg Sewerage System," by Harry Pitts, Superintendent, Parkersburg Sanitary Board. This presentation was followed by a tour of the Parkersburg sewage treatment plant and pumping station.

"Water Discharge from Coal Mines," by S. A. Braley, Administrative Fellow, Mellon Institute, Pittsburgh, Pa.

"South Charleston–Carbide Collection System and Treatment Works,"

(*Continued on page 247a*)

SNOW GATES

for

SEWAGE TREATMENT PLANTS

All types of cast iron gates manufactured in either square or circular opening in sizes up to and including 72 inches.

ALL SNOW GATES and Lifts are "Parkerized" for protection against rust and corrosion.

Over 40 years continuous service to the industry.

We will be pleased to quote on any type of water controlling equipment.

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Link-Belt Co.
Stuart Corp.
Webster Mfg., Inc.

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Chicago Pump Co.
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Johns-Manville Sales Corp.
Koppers Co., Inc.
Perry-Austen Mfg. Co.
Stebbins Engr. & Mfg. Co.
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Eimco Corp.
Infilco Inc.
Lakeside Engineering Corp.
Link-Belt Co.
Pacific Flush Tank Co.
Penberthy Mfg. Co., Div. of Buffalo-Eclipse Corp.
Walker Process Equipment Inc.
Wemco Div., Western Machinery Co.
Zimmer & Francescon

Diffusers, Gas (*also see* Aerators)
American Well Works
Carborundum Co.
Chicago Pump Co.
Eimco Corp.
Infilco Inc.
Walker Process Equipment Inc.
Yeomans Brothers Co.

Digestion Tank Equipment
Alpha Ltd. (Switzerland)
American Well Works
Ralph B. Carter Co.
Chicago Pump Co.
Dorr-Oliver Inc.
Eimco Corp.
Gorman-Rupp Co.
Hardinge Co., Inc.
Infilco Inc.
Jeffrey Mfg. Co.
Lakeside Engineering Corp.
Link-Belt Co.
Pacific Flush Tank Co.
Smith & Loveless, Inc.
Vapor Recovery Systems Co.
Walker Process Equipment Inc.
Yeomans Brothers Co.
Zimmer & Francescon

Distributors, Rotary
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American Well Works
Ralph B. Carter Co.
Dorr-Oliver Inc.
Eimco Corp.
Infilco Inc.
Lakeside Engineering Corp.
Link-Belt Co.
Pacific Flush Tank Co.
Smith & Loveless, Inc.
Walker Process Equipment Inc.
Yeomans Brothers Co.
Zimmer & Francescon

Dryers
Alpha Ltd. (Switzerland)
Combustion Engineering, Inc.
Eimco Corp.
Hardinge Co., Inc.
Komline-Sanderson Engr. Corp.
Link-Belt Co.
Nichols Engr. & Research Corp.
Stuart Corp.

Ejectors
Komline-Sanderson Engr. Corp.
Smith & Loveless, Inc.
Tex-Vit Supply Co.
Yeomans Brothers Co.

Engineers (*see* Directory of Engineers)

Engines (Sludge Gas and Petroleum Fuels)
Climax Engine Mfg. Co.
Fairbanks, Morse & Co.
Waukesha Motor Co.
Worthington Corp.

Fans (*also see* Air Compressors, Blowers, and Compressors)
Chicago Pump Co.
Lakeside Engineering Corp.
Westinghouse Electric Corp.

Filter Equipment, Trickling
Alpha Ltd. (Switzerland)
American Well Works
Ralph B. Carter Co.
Dorr-Oliver Inc.
Dow Chemical Co.
Eimco Corp.
Filtration Equipment Corp.
Industrial Materials Co.
Infilco Inc.
Keasbey & Mattison Co.
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Lakeside Engineering Corp.
Nichols Engr. & Research Corp.
Pacific Flush Tank Co.
Smith & Loveless, Inc.
Trickling Filter Floor Inst.
Walker Process Equipment Inc.
Yeomans Brothers Co.
Zimmer & Francescon

Filter Materials
Carborundum Co.
Filtration Equipment Corp.
Glenn Chemical Co.
Graver Water Conditioning Co.
Industrial Materials Co.
Johns-Manville Sales Corp.
Vulcan Materials Co.

Filters, Diatomaceous Earth
Graver Water Conditioning Co.
Yeomans Brothers Co.

Filters, Vacuum (*also see* Vacuum Filters)
Bird Machine Co.
Dorr-Oliver Inc.
Eimco Corp.
Proportioneers Div., B-I-F Industries

Flocculating Equipment
Alpha Ltd. (Switzerland)
American Well Works
Ralph B. Carter Co.
Chain Belt Co.
Dorr-Oliver Inc.
Eimco Corp.
Graver Water Conditioning Co.
Hardinge Co., Inc.
Infilco Inc.
Jeffrey Mfg. Co.
Lakeside Engineering Corp.
Link-Belt Co.
Stuart Corp.
Walker Process Equipment Inc.
Webster Mfg., Inc.
Zimmer & Francescon

Flotation Equipment
Chain Belt Co.
Dorr-Oliver Inc.
Eimco Corp.
Graver Water Conditioning Co.
Komline-Sanderson Engr. Corp.
Yeomans Brothers Co.

Flow Measurement
Bailey Meter Co.
Burgess-Manning Co., Penn Instruments Div.
Filtration Equipment Corp.

Gas Control Equipment
Alpha Ltd. (Switzerland)
Burgess-Manning Co., Penn Instruments Div.
Ralph B. Carter Co.
Chicago Pump Co.
Dorr-Oliver Inc.
Eimco Corp.
Foxboro Co.
Homestead Valve Mfg. Co.
Pacific Flush Tank Co.
Rockwell Mfg. Co.
Vapor Recovery Systems Co.
Walker Process Equipment Inc.
Zimmer & Francescon

Gas Diffusers (*see* Diffusers, Gas)

Gas Holders, Boilers, and Appurtenances
Ralph B. Carter Co.
Chicago Pump Co.
Dorr-Oliver Inc.
Eimco Corp.
Johns-Manville Sales Corp.
Pittsburgh-Des Moines Steel Co.
Walker Process Equipment Inc.

Gaskets
Johns-Manville Sales Corp.
Keasbey & Mattison Co.

Gates
Armco Drainage & Metal Products, Inc.
Filtration Equipment Corp.
Industrial Materials Co.
Snow Gates & Valves, Inc.
Webster Mfg., Inc.

Generators
Climax Engine Mfg. Co.
Fairbanks, Morse & Co.
General Electric Co.
Westinghouse Electric Corp.
Worthington Corp.

Grease Control Materials
Cloroben Chemical Corp.

Grinders (*also see* Shredders and Grinders)
Alpha Ltd. (Switzerland)
American Well Works
Chain Belt Co.
Dorr-Oliver Inc.
Gruendler Crusher & Pulverizer Co.
Jeffrey Mfg. Co.
Yeomans Brothers Co.

Grit Collection and Conditioning Equipment
Alpha Ltd. (Switzerland)
American Well Works
Chain Belt Co.
Chicago Pump Co.
Dorr-Oliver Inc.
Eimco Corp.
Infilco Inc.
Jeffrey Mfg. Co.
Link-Belt Co.
Stuart Corp.
Walker Process Equipment Inc.
Webster Mfg., Inc.
Zimmer & Francescon

WPCF publications

Safety in Wastewater Works

Contains information on hazards, accident statistics, rescue methods, safe practices, and equipment. *56 pages. $0.75 to members; $1.50 to others. Order as Item MOP-1.**

Utilization of Sewage Sludge as Fertilizer

An authoritative evaluation of advantages and limitations of sludge as a soil conditioner. *120 pages. $0.75 to members; $1.50 to others. Order as Item MOP-2.**

Chlorination of Sewage and Industrial Wastes

Reviews history, development, and up-to-date technique of chlorine application. *90 pages. $1.00 to members; $1.25 to others. Order as MOP-4.**

Air Diffusion in Sewage Works

History and modern practice in design, installation, operation, and maintenance of diffuser systems and appurtenances. *75 pages. $1.00 to members; $1.25 to others. Order as Item MOP-5.**

Units of Expression for Wastes and Waste Treatment

Lists of recommended units for quantities ordinarily encountered in wastes and waste treatment. *8 pages. $0.25 to members; $0.50 to others. Order as Item MOP-6.**

Sewer Maintenance

A guide for maintaining a municipal or industrial drainage system in serviceable condition. *About 70 pages. $1.00 to members; $1.50 to others. Order as Item MOP-7.**

Sewage Treatment Plant Design

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Design and Construction of Sanitary and Storm Sewers

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by J. Wiley Finney, Jr., Partner, Howard K. Bell, Consulting Engineers, Lexington, Ky.

"Design of a pH Control System by Analog Simulation," by W. B. Field, Systems Engineer, Union Carbide Olefins Company, South Charleston, W. Va.

"Financing Municipal Sewerage Projects," a panel discussion.

At the Thursday banquet, the Bedell Award for outstanding service to the Association was presented to Glen O. Fortney, Secretary-Treasurer of the Association. The Award was presented by Ralph E. Fuhrman, FSIWA Executive Secretary.

At the anual business meeting the Association voted to change its name to the West Virginia Water Pollution Control Association.

The new officers for the year 1959–60 are:

President: Harry W. Pitts, Jr., Parkersburg.
First Vice-President: Rex C. Pierson, Charleston.
Secretary-Treasurer: Glen O. Fortney, Charleston.

GLEN O. FORTNEY
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NORTH CAROLINA SEWAGE AND INDUSTRIAL WASTE ASSOCIATION

The annual joint convention of the North Carolina Sewage and Industrial Waste Association and the North Carolina Section of the American Water Works Association was held at the Washington Duke Hotel, Durham, N. C., Nov. 9–11, 1959. Registration was about 330.

The conference was a resounding success in all ways and newspaper coverage of the activities was outstanding.

Among the technical papers of prime interest to those in the wastewater field were:

(*Continued on page 249a*)

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Art Niles, FSIWA Treasurer, brought news of Federation activities.

At the business meeting the following officers were elected:

Chairman: R. E. Ebert, Winston-Salem.

Vice-Chairman: L. P. Bloxham, Greenville.

Secretary-Treasurer: D. Y. Brannock, Burlington.

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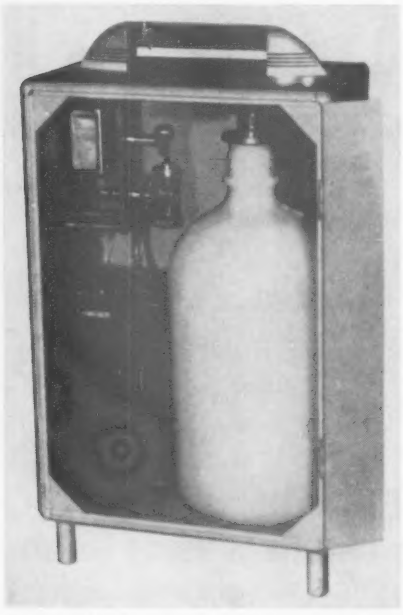

FIGURE 1.—Effluent sampler.

Plug Valves—The availability of a non-lubricated general purpose valve with two Teflon "O" rings in the face of the plug has been announced. Called the "O-Seal," it will effectively double-block and bleed in most services to do the job of two ordinary valves.—Wedge-plug Valve Company, Division of Stockham Valves and Fittings, Birmingham 2, Ala.

Sewer Pipe Repair—The Industrial Pipe Repair Corp., 2100 North Dixie, Wilton Manors, Fla., offers a sewer inspection based on closed-circuit television and a repair service based on in-place mudjacking of grout to the point of infiltration.

Protective Coating—An epoxy compound has been developed for renewing concrete and asphalt surfaces where abrasion and chemical resistance are important. Known as "Epoxicrete 811," the material is excellent for filling spalled areas.—Coast Pro-Seal & Mfg. Co., 2235 Beverly Blvd., Los Angeles 57, Calif.

Bin Vibrator—A new catalog on "pulsating-magnet" vibrators for keeping stubborn bulk materials free flowing is available. The 12-page booklet gives complete descriptions, data, and specifications for 14 standard vibrators, ranging from 2-lb to 950-lb units.—Syntron Company, 1351 Lexington Ave., Homer City, Pa.

Disposable Clothing—A line of disposable clothing for industrial, laboratory, institutional, and commercial use has been announced. The garments available are: shirts, pants, laboratory coats, hats, boots, aprons, and gowns.—Bulletin 700, General Scientific Equipment Co., 7516 Limekiln Pike, Philadelphia 50, Pa.

Protected Gas Pump Impellers—Impellers on gas pumps are now available with a Kanigen coating which protects against sparking and corrosion.—Sutorbilt Corporation, 2966 E. Victoria St., Compton, Calif.

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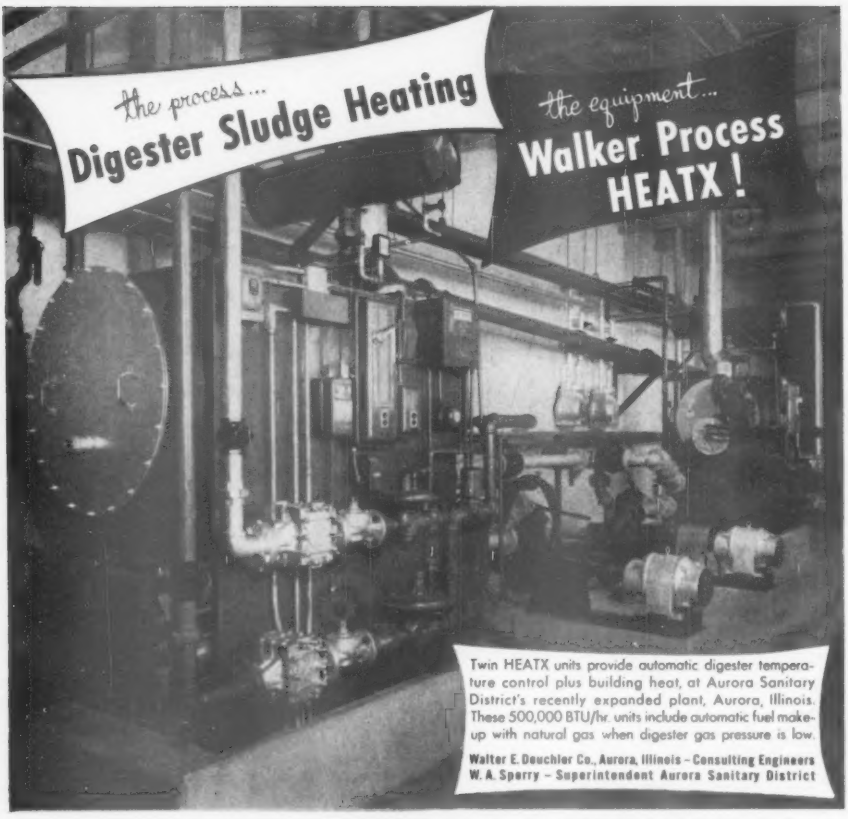
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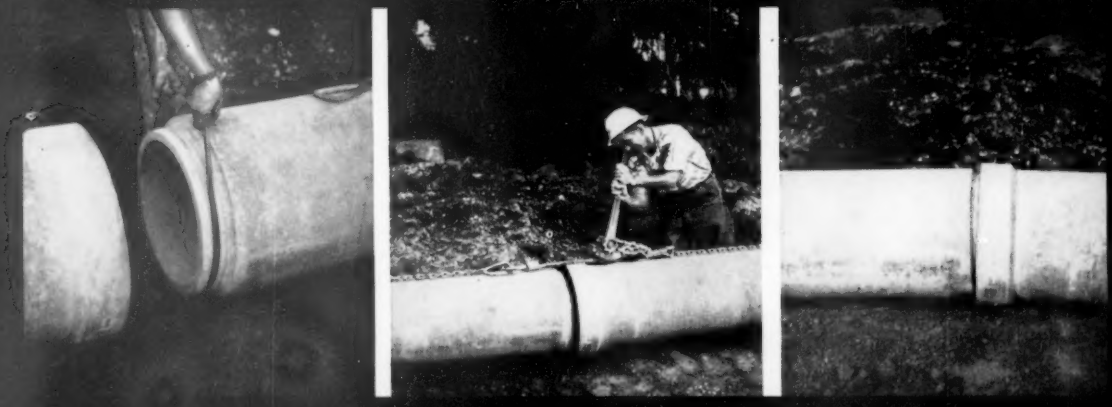

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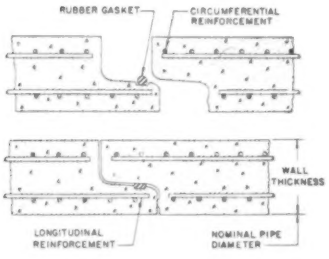

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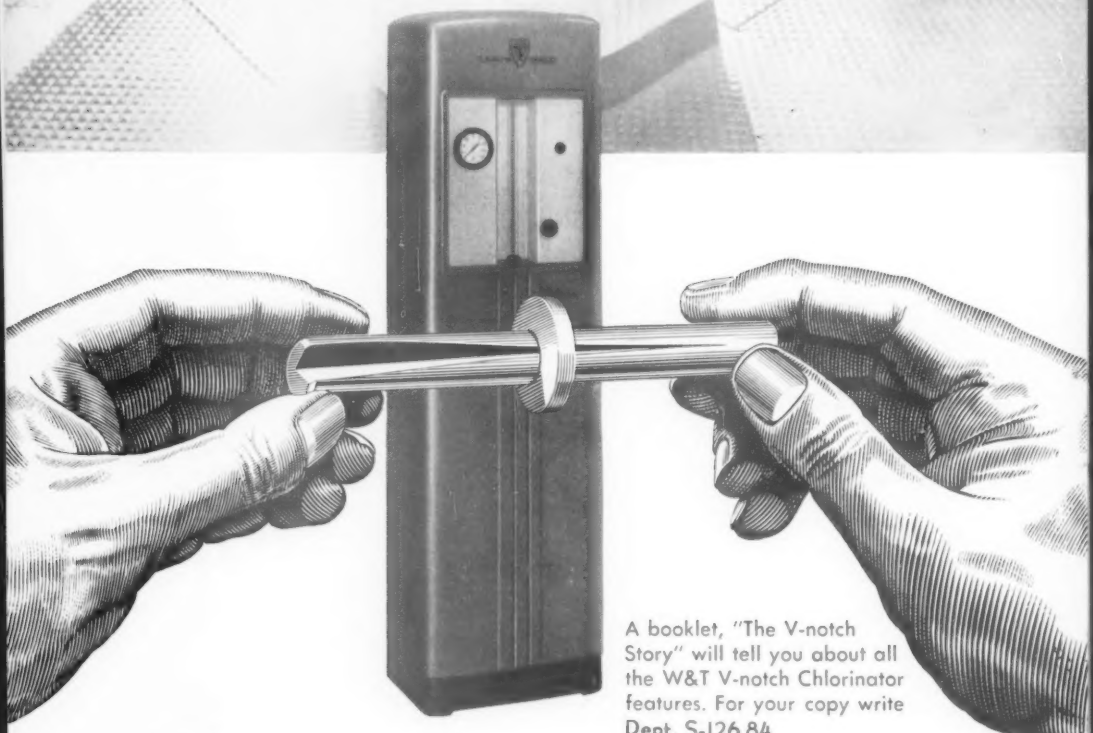

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